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CASSELL & COMPANY, LIMITED, *La Belle Sauvage, London. E.C.*

SANITARY CONSTRUCTION IN BUILDING

SANITARY CONSTRUCTION IN BUILDING

WITH NUMEROUS ENGRAVINGS AND DIAGRAMS

EDITED BY

PAUL N. HASLUCK

HONOURS MEDALLIST IN TECHNOLOGY
EDITOR OF "WORK" AND "BUILDING WORLD"
AUTHOR OF "HANDYBOOKS FOR HANDICRAFTS," ETC. ETC.

CASSELL AND COMPANY, LIMITED

LONDON, PARIS, NEW YORK & MELBOURNE, MCMVI

PREFACE.

Sanitary Construction in Building contains, in a form convenient for everyday use, a comprehensive digest of information, contributed to Building World, one of the weekly journals it is my fortune to edit, and supplies concise information on the general principles and practice of the subject on which it treats.

It may be said that the matter contained in this book consists substantially of articles written by Mr. H. Gilbert Whyatt, A.M.I.C.E., M.R.SAN.I., Borough Engineer of Grimsby. [Formerly Deputy Borough Engineer of Salford, Lecturer on Sanitary Science at Owens College, Victoria University, Manchester, and at the Royal Technical Institute, Salford.]

Readers who may desire additional information respecting special details of the matters dealt with in this book, or instructions on any building trade subjects, should address a question to the Editor of Building World, La Belle Sauvage, London, E.C., so that it may be answered in the columns of that journal.

P. N. HASLUCK.

La Belle Sauvage, London,
September, 1906.

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SANITARY CONSTRUCTION IN BUILDING.

CHAPTER I.

INTRODUCTORY.

It is proposed in this manual to deal with Sanitary Building Construction only so far as regards the sanitary inspector and the Public Health Act (P.H.A.). The Model Bye-laws M.B.L. of the Local Government Board (L.G.B.) have been quoted in full wherever necessary, and explanations of the various clauses and provisions have been given, with a view to making the duty of both the builder and the sanitary inspector perfectly clear on all the points involved. It is desirable, however, for anyone taking up the subject to purchase copies of the P.H.A. and the M.B.L., published by Messrs. Wyman & Sons, Fetter Lane, London, E.C. Messrs. Knight & Co., 227 and 239, Tooley Street, London, S.E., publish the various P.H.A., 1875 to 1892, in one volume and well indexed, at 6s. 6d.; they also publish the "Annotated Model Bye-laws," indexed and illustrated, the seventh edition of which was issued in 1905 at 16s. net. This latter volume contains a number of additional and alternative clauses, these being quoted or referred to, as the need arises, in the present manual.

Sanitary engineering, sanitary inspection, and P.H.A. are not modern innovations; they are merely a revival of very ancient legislation. We find within the first five books of the Old Testament the sanitary laws as to scavenging, pure water, clean food, and bodily cleanliness, as observed by the Israelites 3,300 years ago. "The health of the people is the highest law," wrote a Latin author about 2,000 years ago; and in his time the law was observed, for we still find

in Rome the remains of the great sewers, the aqueducts, and other great sanitary engineering schemes.

In a paper on "Sanitary Houses and How to Select One," F. A. Bond, M.B., writes: "In the olden days a habitation was merely a place to dwell in. In primeval times it might be a cave, with a few rough portions of rock placed before the entrance to act as a door; or it might have been a hole in the ground, with simply a few branches of trees covered over it to act as a roof; or it might have been an abode built in a tree, composed of nothing but branches twisted together, after the manner of a bird's nest, and probably suggested by it. All these, in different climes, have been used as the home of man." But necessity and the progress of civilisation demanded a means of shelter more adaptable to varying circumstances, and the one-roomed hovel was built of "rough stones piled one on the other in rude, unshapely masses, the crevices being filled with mud to keep out the wind and rain. Advancing further, the single room was made into two, then one was built above the other, mud was replaced by mortar, and bricks took the place of stones. One change brought another, and the house grew and increased step by step and stage by stage."

But, while civilisation increased, and in nearly every science rapid advances were made, the science of Sanitary Building Construction lagged woefully behind. Houses were built without reference to their surroundings, and regardless of proper means of drainage; no attention was paid to circulation of air, nor to the nature of the subsoil; and as dwellings became more crowded in the vicinity of towns, insanitary conditions increased both in number and in intensity. The state of towns became so bad that in 1842 a Royal Commission was appointed to inquire into the condition of the housing of the poor with regard to the drainage and water supply of towns. The inquiry was long; the revelations were appalling; and the result was the passing of the P.H.A., 1847. This Act was amended many times, and the Act and amendments were consolidated in 1875, as the P.H.A., 1875. Over a dozen Acts amending it, and more than a score of Acts extending it, have been passed since then.

Various Local Government Acts have divided the country

up into districts, each with its elected body, whose function it is to secure the observance of the "supreme law—the health of the people," as set forth in the P.H.A.

An army of officials is employed in carrying out the duties laid upon the local authorities, and an army of inspectors is also employed to detect infringements of the Acts on the part of property-owners and occupiers. Until within the last few years anyone was thought competent to fill the position of a sanitary inspector; but at the present time, although the law is silent as to the inspector's qualifications, there is hardly a local authority in England which does not insist that applicants for the position shall possess a certificate of competency granted by some recognised examining body.

It will be found that the Acts do not themselves contain provisions as to the method of construction, but merely give power to Local Authorities to make bye-laws on these matters, which bye-laws must receive the sanction of the L.G.B.

§ 157 of the P.H.A., 1875 (38 & 39 Vict. c. 55), provides that "every Urban Authority may make bye-laws with respect to the following matters; that is to say,

"(1) With respect to the level, width, and construction of new streets, and the provisions for the sewerage thereof;

"(2) With respect to the structure of walls, foundations, roofs, and chimneys of new buildings, for securing stability and the prevention of fires, and for purposes of health;

"(3) With respect to the sufficiency of the space about buildings to secure a free circulation of air, and with respect to the ventilation of buildings;

"(4) With respect to the drainage of buildings, to water-closets, earth-closets, privies, ashpits, and cesspools in connection with buildings, and to the closing of buildings or parts of buildings unfit for human habitation, and to the prohibition of their use for such habitation:

"And they may further provide for the observance of such bye-laws by enacting therein such provisions as they think necessary as to the giving of notices, as to the deposit

of plans and sections by persons intending to lay out streets or to construct buildings, as to inspection by the Urban Authority, and as to the power of such Authority (subject to the provisions of this Act) to remove, alter, or pull down any work begun or done in contravention of such bye-laws."

It would appear, after superficial consideration of the matter, that the only thing necessary to secure Sanitary Construction throughout the country would be for the L.G.B. to draw up a model code of Building Regulations and to enforce them. This they did, so far as the above section gave them power. It was found during succeeding years that bye-laws on other subjects were necessary, and in the P.H.A. Amendment Act, 1890, it is provided as follows (§ 23) :—

"23.—(1) § 157 of the P.H.A., 1875, shall be extended so as to empower every Urban Authority to make bye-laws with respect to the following matters; that is to say :—

"The keeping water-closets supplied with sufficient water for flushing.

"The structure of floors, hearths, and staircases, and the height of rooms intended to be used for human habitation;

"The paving of yards and open spaces in connection with dwelling-houses; and

"The provision in connection with the laying out of new streets of secondary means of access where necessary for the purpose of the removal of house refuse and other matters.

"(2) Any bye-laws under that section as above extended with regard to the drainage of buildings, and to water-closets, earth-closets, privies, ashpits, and cesspools, in connection with buildings, and the keeping water-closets supplied with sufficient water for flushing, may be made so as to affect buildings erected before the times mentioned in the said section.

"(3) The provisions of the said section (as amended by this Act), so far as they relate to bye-laws with respect to the structure of walls and foundations of new buildings for purposes of health, and with respect to the matters mentioned in sub-sections (3) and (4) of the said section, and with respect to the structure of floors, the height of rooms

to be used for human habitation, and to the keeping of water-closets supplied with sufficient water for flushing, shall be extended so as to empower rural authorities to make bye-laws in respect to the said matters, and to provide for the observance of such bye-laws, and to enforce the same as if such powers were conferred on the rural authorities by virtue of an order of the L.G.B. made on the day when this part of this Act is adopted; and § 158 of the P.H.A., 1875, shall also apply to any such authority, and shall be in force in every rural district where this part of this Act is adopted.

"(4) Every Local Authority may make bye-laws to prevent buildings which have been erected in accordance with bye-laws made under the P.H.A. from being altered in such a way that if at first so constructed they would have contravened the bye-laws."

CHAPTER II.

SOILS, SUBSOILS, AND SITES.

ALTHOUGH the sanitary inspector is very seldom called upon to report as to the fitness of a site for the erection of a row of cottages or a group of villa residences, he is frequently consulted at a later period, when mysterious diseases break out, or provisions putrefy within a few hours after being placed in the larder, or water shows itself in the basement, or peculiar odours are detected. It is proposed in this chapter to deal with the question of soils, subsoils, and sites, with reference to their suitability for building purposes, with remediable defects and incidental defects in sites, and to discuss the views expressed by the L.G.B. and the Houses of Parliament on the whole question.

In determining the suitability of a site, it is not necessary, however desirable, to possess more than a smattering of the science of geology, and it is palpably impossible here to do more than mention the chief points of the science of the earth's crust.

A geologist will hear nothing of soils and subsoils—to him these are rocks; whilst in ordinary language "rock" is generally understood to mean a characteristically hard substance, the geologist employs the term to designate mineral masses of all kinds, whether hard or soft. To him, clays and sands are rocks quite as much as are granites and marbles. For our present purpose, however, it is deemed better to use the words in their ordinary sense, calling these soft rocks by their ordinary names, or including them generally in the term "subsoils," as occasion requires; and using the term "soil" to mean the *humus*, or the uppermost layer, in which may be found an admixture of vegetable and animal matter with the minerals.

Rocks are divided by the geologist into three main classes: (1) The igneous, or those formed by fire; (2) the aqueous, or those formed by water; and (3) the metamorphic, con-

sisting of either of the foregoing, materially altered in character by the action of other elements. There is a fourth class, the æolian, formed by the wind blowing accumulations of loose material into favourable spots, but they do not play a conspicuous part in geology; we have examples of them in the sandhills found by the margin of the sea.

Rocks of the igneous class, which are rarely found near the surface in populated districts, comprise the granites, basalts, trap, lava, and other volcanic or plutonic rocks; neither are we much concerned with the metamorphic rocks, which comprise the marbles, slates, and others of similar composition.

The aqueous or sedimentary rocks—that is, those formed by the action of the water—include the sandstones, limestones, sand, chalk, clay, etc.; and these are again divided into three main classes, namely, the siliceous, or sandstones; the calcareous, or limestones; the argillaceous, or clays. These form the greater portion of the subsoil with which the sanitary engineer has to deal, and a little space must be devoted to considering them.

The physical characteristics of each of these classes of aqueous rocks differ considerably; hence their varying degrees of fitness and suitability, or the reverse, as building sites, the sands being exceedingly permeable, loosely compacted, and light, the clays extremely dense, impervious, and heavy; and between the two extremes there are almost infinite gradations of density and porosity.

There is one geological point that should be specially noticed: The various strata which go to make up the earth's surface are superimposed one upon the other in a certain definite order, which is never reversed. A particular stratum or a whole series of strata may be absent from the series, but the order in which they are found may be regarded as invariable.

There remains for consideration another soil, which, although it finds no place in manuals of geology, nevertheless is of universal occurrence in this country, and causes the sanitarian more trouble than all other rocks and soils combined. The allusion is to "tipped" land, or "made ground," as it is indifferently called. There are in almost every town large tracts of land lying below the level of the

town. Perhaps these may have been pits out of which clay for brickmaking has been removed, and these inequalities may have been filled up with whatever happened to be available—with brickbats, cinders, the material dug out of other foundations, and not infrequently with much less innocent substances than these, such as road scrapings, the contents of ashpits and middens, market refuse, fish and slaughter-house offal, vegetable and animal refuse of every description; in other cases, chemical or trade refuse of various kinds has been employed. Abuses of this sort are now rendered almost impossible, if the law is enforced, but the duty of prevention rests with the sanitary inspector, who derives his authority from § 49 of the P.H.A., 1875, in Urban Districts. The section reads as follows:—

"§ 49. Where in any Urban District it appears to the Inspector of Nuisances that any accumulation of manure, dung, soil, or filth, or other offensive or obnoxious matter, ought to be removed, he shall give notice to the person to whom the same belongs, or to the occupier of the premises whereon it exists, to remove the same; and if such notice is not complied with within twenty-four hours, the manure, dung, soil, or filth, or matter referred to, shall be vested in and be sold or disposed of by the Urban Authority, and the proceeds thereof shall be applied in payment of the expenses incurred by them in the execution of this section; and the surplus (if any) shall be paid on demand to the owner of the matter removed.

"The expenses of removal by the Urban Authority of any such accumulation, if and so far as they are not covered by the sale thereof, may be recovered by the Urban Authority in a summary manner from the person to whom the accumulation belongs, or from the occupier of the premises, or (where there is no occupier) the owner."

This gives an inspector complete power in an Urban District to cause any accumulation of offensive matter to be removed. § 91 applies to both rural and urban districts: "For the purposes of this Act . . . (4) any accumulation or deposit which is a nuisance or injurious to health . . . shall be deemed to be nuisances liable to be dealt with summarily in manner provided by this Act."

Succeeding clauses, §§ 92 to 111, show what steps may

be taken by the inspector and the Sanitary Authority to abate the nuisance, and recover the cost if the occupier or owner does not carry out the work. Inspectors should be thoroughly conversant with every word of these twenty-one sections.

It is quite possible that the deposits of foul matter may have been made in the past, before the appointment of an inspector, or before the Sanitary Acts began to be so rigorously carried out as at present; and it rests with the inspector to prevent such land being used as sites for the erection of dwellings.

"Much of this material is in a state of putrefaction, and it has been found by experiment that the organic putrefiable substances do not entirely disappear even in three years' time from their first being laid down. Such ground as this is the very worst upon which houses could be built, and yet it is very common in the suburbs of all towns, and is often the subject of alluring advertisements of 'eligible sites for buildings.'"—Ransome, "Soils and Sites," p. 7.

In consequence of a Report by Drs. Parkes and Sanderson on the sanitary condition of Liverpool, the L.G.B. in 1877, in their M.B.L. respecting new streets and buildings, framed a clause which now reads as follows:—

M.B.L. No. 10: "A person who shall erect a new building shall not construct any foundation of such building upon any site which shall have been filled up with any material impregnated with fæcal matter or impregnated with any animal or vegetable matter, or upon which any such matter may have been deposited, unless and until such matter shall have been properly removed, by excavation or otherwise, from such site."

This bye-law, however, was only in force in a few towns in the kingdom; and progress being found too slow, Parliament consequently, in the P.H.A. Amendment Act, 1890, inserted the following clause:—

§ 25: "It shall not be lawful to erect a new building on any ground which has been filled up with any matter impregnated with fæcal, animal, or vegetable matter, or excavation or otherwise, or shall have been rendered or have become innocuous.

"Every person who does or causes, or wilfully permits

to be done, any act in contravention of this section, shall for every such offence be liable to a penalty not exceeding £5, and a daily penalty not exceeding 40s."

The wording, it will be noticed, is rather broader than in the bye-law, as it gives a builder the opportunity to "render" it "innocuous," if it has not already "become" so. It also provides for a cumulative penalty, calculated to deter a builder from erecting dwelling-houses on foul land.

It must be noted that not every town and district has its regulations based on the M.B.L.; and consequently it may happen that the M.B.L. No. 10 is of no help to the sanitary inspector. It must also be noted that the P.H.A. Amendment Act, 1890, is a *permissive* Act, and must be *adopted* before § 25 is available for application.

For any district which is so much behind the times in sanitation, it will be the first duty of the sanitary officials to draw up a new code of regulations.

The Medical Officer of Health of one of our large county boroughs has prepared a Report, accompanied by a map, showing the whole of the land in the borough which has been filled up with foul or even doubtful material. Whenever any plans for new buildings upon any of these areas are deposited with the Corporation for approval, a careful examination of the land is made, a trial hole to the full depth of the filled material is excavated, and if the material is innocuous, the medical officer gives a certificate to that effect. If the foul matter has not become innocuous, the Corporation withhold their consent until the builder has removed it or rendered it innocuous.

This plan is well worthy of adoption, as it will save much friction by preventing any dispute whilst the houses are actually in course of erection. In many of the smaller towns and districts the examination of deposited plans is part of the sanitary inspector's work; and if he is well acquainted with the geology of the district, and knows the position of the clay land and the tipped land, he will be able to enforce the precepts and laws of sanitation much better than one who knows nothing of the science.

In considering the sanitary suitability of the various subsoils, the two chief points to be inquired into are (*a*) the

quantity and nature of the air in the interstices of the soil, and (*b*) the quantity, quality, and movements of the water in the interstices of the soil.

The quantity and nature of the air occupying the interstices of the soil will be considered first. "The hardest rocks alone are perfectly free from air; the greater number even of dense rocks, and all the softer rocks, and the loose soil covering them, contain air. The amount is in loose sands often 40 or 50 per cent.; in soft sandstones, 20 to 40 per cent.

"The amount of air in rocks can be roughly estimated, in the case of rather loose rocks, by seeing how much water a given bulk will absorb, which can be done by measuring the water before and after the weighed or measured rock is inserted in it, or by weighing the rock after immersion. But a more exact plan is to weigh a piece of the rock when dry; to thoroughly saturate it with water, and weigh again, so as to obtain the weight of the water it has taken up. The specific gravity of the rock having been previously determined . . . the calculation is—

$$\frac{\text{wt. of water taken up} \times 100}{\text{wt. of dry rock} \div \text{spec. g.}} = \text{percentage of air."}$$

(Parkes, "Hygiene." Ch. VIII. Sec. 1, Sub-sec. 1.)

Or when the soil is loose, dry it at 212° F., and powder it, but without crushing it very much; carefully take the cube contents, then pour upon it a measured quantity of water until a thin layer is seen above it. The calculation is—

$$\frac{\text{Amount of water used} \times 100}{\text{cubic centimetres of dry soil}} = \text{percentage of air.}$$

"The subterranean atmosphere thus existing in loose soils and rocks is in continual movement, especially when the soils are dry; the chief causes of movement are the diurnal changes of heat in the soil and the fall of rain, which must rapidly displace the air from the superficial layers, and at a later date, by raising the level of the ground water, will slowly throw out large quantities of air from the soil.

"Local conditions must also influence the movement; a house artificially warmed must continually be fed with air from the ground below, and doubtless this air may be drawn from great depths."

Now as regards the nature of this ground air, Dr. Parkes says: "It is mostly very rich in carbonic acid. . . Occasionally it contains carburetted hydrogen, and in moist soils, when the water contains sulphates, a little sulphuretted hydrogen may be found."

Dr. Ransome says ("Soils and Sites," p. 8): "The ground air is not exactly like the air of the atmosphere around us. It is true that it is a mixture of the same gases—oxygen, nitrogen, and carbonic acid; but in atmospheric air there are usually only 4 parts per 10,000 of carbonic acid, and 20 per cent. by volume of oxygen. In ground air the oxygen at a depth of a few yards diminishes in some cases to 15 per cent., and the carbonic acid may rise to as much as 8 per cent.—200 times more than in atmospheric air. This tendency to substitute carbonic acid for oxygen increases the deeper we get into the ground.

"Professor Pettenkofer, to whom we owe much of our knowledge of underground physics, found that in the neighbourhood of Munich the carbonic acid varied from 1·58 per 1,000 volumes at a depth of 5 ft., to 18·38 at a depth of 13 ft. At this last-mentioned depth, then, the air would be quite irrespirable, and it would at once extinguish a light. It was at Dresden that Fleck found the large proportion of 80 parts of this gas per 1,000."

Dr. Ransome then proceeds to urge the importance of keeping this ground air out of the house, and the danger of breathing such impure air. What, then, must be the nature of the emanations from the refuse sometimes used to fill up low-lying land? Imagine the consequence of breathing the effluvia arising from the rotting offal of a fish market or a vegetable market, together with an admixture of ashpit refuse and excreta!

The L.G.B., acting on the advice of their inspectors, have drawn up a M.B.L. specially intended to shut out this ground air. The means suggested also serve the purpose of shutting out underground waters to a great extent. The bye-law is:—

M.B.L. No. 11: "Every person who shall erect a new domestic building shall cause the whole ground surface within the external walls of such building to be properly asphalted or covered with a layer of good cement concrete, at least 6 in. thick, or 4 in. thick if properly grouted."

The annotator in Messrs. Knight's edition makes the following Note : " The sanitary advantages of this clause are considerable. Residence on a damp subsoil as the foundation for a house has long been known to favour the prevalence of disease, such as pulmonary consumption, hence regulations to prevent dampness rising from the soil beneath a house into the interior of the house are obviously desirable. All soils and rocks are more or less pervious, and this is especially the case with gravel, sand, and chalk, which are popularly deemed to afford the best subsoils for dwelling-houses. Indeed, chalk will hold some 16 per cent. of its weight in water ; in a similar way large volumes of ground air are held in its pores, and both this and the moisture, when drawn up into a house by the influence of temperature, or as the effect of a direct suction resulting from fires, etc., tend to injurious results. The injurious influence of ground air in dwellings, especially in thickly populated places, is becoming more and more recognised. Where the foundations are laid in some specially dry formation, serious and fatal disease has followed on the soakage of filth from a leaky drain on neighbouring premises, or otherwise, into the soil beneath a house. This source of danger, which has been found especially grave in the case of pervious gravels and fissured rocks, is obviated by the adoption of the model clause. It is to be remembered that the extra cost of adopting the precaution prescribed in this clause cannot add greatly to the cost of a house, seeing that a cubic yard of concrete costs perhaps from 10s. to 15s., and, at 6 in. thick, will cover an area of 54 sq. ft. As it is an additional safeguard to require the upper surface of the concrete to be grouted and floated over to a smooth surface with cement, a reduced thickness is permissible where this is done. . . . It may further be pointed out that in many cases—as in halls, lobbies, and certain kitchen offices—the concrete may form the finished flooring, and thus save any additional cost for other kinds of flooring."

Ground air is very probably instrumental in assisting the growth of dry rot. Very little is known as yet as to the origin of this fungus, but it is certain that a closed-in space to which ground air has access is extremely favourable to its development, whilst a space freely ventilated

and from which ground air is excluded is very seldom attacked.

Mr. Keith D. Young mentions a case which shows the importance of covering sites with a layer of concrete: "In a cottage situated about twenty or thirty yards from the shaft of a disused coal mine, certain cases of illness had occurred, the symptoms of which pointed to a very dangerous gas called carbon monoxide. The disused shaft referred to communicated with a mine in work. To facilitate ventilation in the mine which was in work, a fire had been lit and suspended in the shaft of the disused mine, and this furnace had set fire to the coal in the latter mine. The cottage in question is the end of a row, and has a cellar which has an opening into the outer air. This opening was usually covered over by a piece of board which effectually excluded the air from the cellar. For several weeks previous to the occurrence of the illness in question, the surface of the ground had been frozen hard and covered with snow. What, therefore, happened was this: the gas generated in the mine, finding no way of exit through the frozen and snow-covered surface of the ground, had penetrated the subsoil until it reached the ground under the house, where it found a ready exit. In the adjoining house the cellar opening was covered with a board which did not fit well, and consequently allowed some of the gas to escape. In this cottage the inmates suffered from the same illness, but in a much less severe form." ("Sanitary Building Construction," *Journal of the Sanitary Institute*, Vol. xv., Part 1, p. 39.)

Dr. Ransome quotes another instance, as narrated by Professor Pettenkofer, which shows how far ground air "may travel when sucked in by the in-draught caused by warm and ascending air inside a house.

"In December, 1859, the Chaplain of St. Ulrich's Church, at Augsburg, was suddenly seized with a serious illness, the nature and cause of which were inexplicable. The Sisters of Mercy who nursed him were one after another seized with the same symptoms—pain and congestion of the head, fainting, etc. The symptoms always became aggravated when the weather got colder. After some time, no improvement having appeared, a friend who came to see him one day exclaimed, on entering the room: 'There is an escape

of gas!' This was denied by all connected with the house, and declared by the doctor to be immaterial, as the patient was now pronounced to be undoubtedly suffering from fever. At length, however, a person was sent for from the gas office, and he at once said there was an escape, but confessed himself unable to discover its source. The patient, however, acted on the hint, and having left the house in spite of the doctor, recovered in a few days. No sooner was he gone and the windows of his apartment thrown open, and the fire let out, than his next neighbour was attacked by the very same symptoms. He too, recovered, at once by a rapid flight from the house.

"It was impossible to examine the underground pipes at the time, as the ground was frozen hard. However, at the end of six days this was done, and an escape was discovered in the main pipe which ran in the centre of the street some 20 ft. off, the gas escaping in such quantities as to burn briskly when lighted.

"The coldness of the weather had necessitated larger fires in the house, and the increased heat developed a current of air from the ground into the house, the gas being sucked up with it. When the patient had left the house, his room was allowed to cool, and the current of air and gas was thus diverted to the apartments of his neighbour." ("Soils and Sites," p. 10.)

It will, of course, be readily perceived that if in these two cases the carbon monoxide and the coal gas could travel long distances underground, and that if it may be drawn into houses by the suction of the warm air, any other air or gas, whether pure or deleterious, that the ground may contain may with equal facility be thus conveyed into the interior of the house.

There is this peculiarity also to notice—foul water travelling a distance underground is filtered and purified, but foul gases travelling a considerable distance through ground are not.

The sanitary inspector has not only to prevent houses being erected on insanitary land, but after the houses are erected he must prevent the earth becoming fouled and polluted with house refuse, or the leakage of drains and midden privies. It will be seen presently how this ground air is

forced into houses by the movements of the subsoil water, and how necessary it is that the concrete bed should be absolutely impervious.

The second point in the inquiry as to the sanitary suitability of a site concerns the quantity, quality, and movements of the water present in the subsoils. When air as well as water is present in the soil, the soil is merely moist, the quantity varying with the power of the soil to absorb and retain water, and with the supply of water to the soil, either from above as rain or from below by capillary attraction.

Dr. Parkes says that "a loose sand may hold 2 gal. of water in 1 cub. ft., and ordinary sandstone may hold 1 gal. Chalk takes 13 to 17 per cent.; clay, if not very dense, 20; ordinary garden soil (humus), as much as 40 to 60, and retains it strongly. . . . The driest granite and marbles will contain from ·4 to 4 per cent. of water, or about a pint in each cubic yard."

Dr. Ransome says: "Except in very hot climates, or occasionally in very hot summers in this country, all soil is more or less damp, and generally, even in the hottest weather, we have only to dig a few inches into the ground before we find a certain degree of dampness." ("Soils and Sites," p. 11.)

But at a certain depth below the surface—a depth that varies with different soils and strata—we find that the interstices of the soil are filled with water, air no longer being present; the ground is saturated, so that "except in so far as its particles are separated by solid portions of soil, there is a continuous sheet of water." (Dr. Parkes.) Any space made by the spade speedily fills with the water flowing into it from the porous soil around. This water is called the ground water, or the subsoil water, or the "ream" water.

This subterranean sheet of water is at very different depths below the surface in different soils; sometimes it is only two or three feet from the surface, in other cases as many hundreds. In a marsh it rises quite to the surface. The level depends, says Dr. Parkes, "on the compactness or permeability of the soil, the ease or difficulty of outflow, and the existence or not of an impermeable stratum near or far from the surface. The underground sheet of water

is not necessarily horizontal, and in some places it may be brought nearer to the surface than others by peculiarities of ground. The water is in constant movement, in most cases flowing towards the nearest watercourses or the sea, at a rate which has not yet been perfectly determined. . . . The level of the ground water is constantly changing. It rises or falls more or less rapidly, and at different rates in different places; in some cases its movement is only a few inches either way, but in most cases the limits between its highest and lowest levels in the year are several feet.

"The causes of change in the level of the ground water are the rainfall, pressure of water from rivers or the sea, and alterations in the outfall, either increased obstructions or the reverse. The effect of the rainfall is sometimes only traceable weeks or even months after the fall, and occasionally, as in plains at the foot of hills, the level of the ground water may be raised by rainfalls occurring at long distances. The pressure of water in the Rhine has been shown to affect the water in a well 1,670 ft. away."

The consequences of living on a damp soil hardly come within the purview of a sanitary inspector; they are rather the concern of the medical officer. There is, however, strong evidence that it predisposes to rheumatism, neuralgia, catarrh, phthisis, ague, and other affections; that where the subsoil water level is very near the surface, malarious fevers are rife; and that where the level alters considerably and at frequent intervals, thus forcing the ground air to evolve from the surface, paroxysmal fevers occur just as regularly as the water level alters. Where the ream level is below the basement of the house, a layer of concrete is all that is necessary; but where the level is higher than the basement floor, something should be done to lower it.

The L.G.B. on this point have issued the following as a Model Bye-law :—

M.B.L. No. 59: "Every person who shall erect a new building shall cause the subsoil of the site of such building to be effectually drained by means of suitable earthenware field-pipes, properly laid to a suitable outfall, wherever the dampness of the site renders such a precaution necessary.

"He shall not lay any such pipe in such a manner or in such a position as to communicate directly with any sewer

or cesspool, or with any drain constructed or adapted to be used for conveying sewage, but shall provide a suitable trap, with a ventilating opening, at a point in the line of the subsoil drain as near as may be practicable to such trap." (See Figs. 1 and 2.)

Upon this the annotator comments as follows :—

" The necessity of draining the subsoil beneath buildings

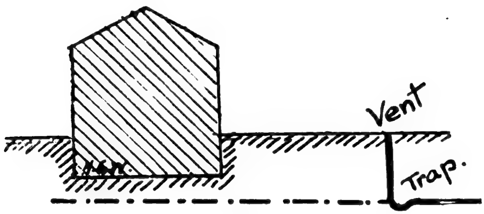


Fig. 1.

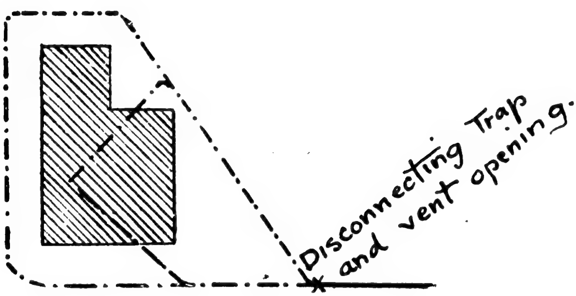


Fig. 2.

Figs. 1 and 2.—Subsoil Drainage, Section and Plan.

has already been referred to (Clause No. 11). Owing to the pervious character of the drain necessary for this purpose, it is imperative that sewer air should not be allowed to gain entrance to it and from it into the surrounding soil. Hence the conditions specified in the second paragraph. Where the system of sewerage in operation is that known as the 'separate system'—that is, where such part of the rainfall as is free from serious pollution is excluded from the sewers

and conveyed separately to some watercourse or other place, a suitable outfall for this pipe-drain may easily be obtained by connecting it with the rainwater drain. Under other circumstances it is desirable that the outfall should be either direct into the open air, or, where it must be conveyed to the sewer, that the nearest approach to this should be obtained in the manner shown (Figs. 1 and 2). Where, however, a trap is used to preclude the entry of sewer air or cesspool air into the pipe-drain, arrangements should be made to ensure the maintenance, even in the driest seasons, of a sufficiency of water in the trap. Thus, a fresh-water tap may be fixed for this purpose near the ventilating opening."

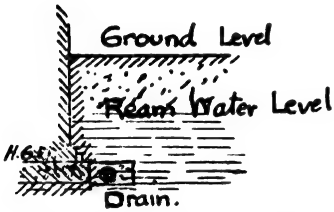


Fig. 3.—Position of Subsoil Pipe-drain.

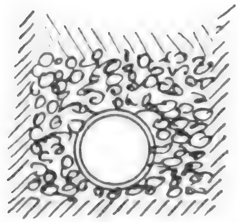


Fig. 4.—Open-jointed Pipe-drain, surrounded with gravel.

A down-pipe may be with advantage connected to this opening.

The L.G.B. have in this M.B.L. touched nearly every point of the one method suggested. The closeness of the drains to each other will be determined by the porosity of the soil. The pipes should be of unglazed pottery and butt-jointed, not socketed. It is important, however, that they should be truly laid to an even gradient, or they merely become underground cisterns, aggravating the evil they were intended to cure. They should be surrounded or covered with a layer of gravel, 6 in. thick, to facilitate the percolation of water. (See Figs 3 and 4.) The discharge from these drains may, if in the country, be led into a watercourse; or, if in a town, they should be led into a trapped disconnecting chamber or gully, discharging thence into the main drain or public sewer. (See Figs. 5 and 6.)

These subsoil drains should never be used for the conveyance of sewage, and never used for the ventilation of the sewers. It is imperative that they themselves should be ventilated; the upper ends should be in communication with the open air, so that if by any mischance the trap at the outlet becomes unsealed, the sewer gas may have an opportunity to escape without contaminating the subsoil.

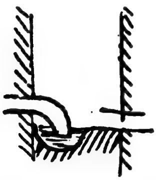


Fig. 5.

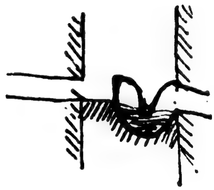


Fig. 6.

Figs. 5 and 6.—Methods of Trapping Drain Outlets.

The intercepting chamber at the outlet should have the character of a ventilated manhole sufficiently large to admit of thorough inspection.

If the sanitary inspector has sufficient knowledge of

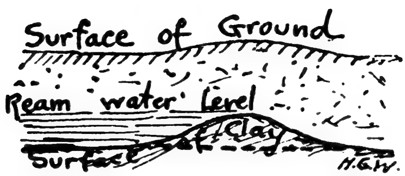


Fig. 7.—Obstruction of Subsoil Water.

geology, he may possibly discover much cheaper means of lowering the subsoil water than by laying an expensive network of deep drains. He may find an embankment of clay, which acts as an underground dam, as shown at Fig. 7, and prevents the flow of the subsoil water; a ditch cut through this and filled with gravel, brickbats, or other pervious material, may be an effectual, permanent, and inexpensive remedy. He may find that the water runs down

a hill towards the house, and that a similar ditch dug farther up the hill may divert the water (see Figs. 8 and 9). He may find that the house is very unwisely placed in the centre of a depression, like a teacup in a saucer (see Fig. 10), so that there is apparently no flow of underground water in

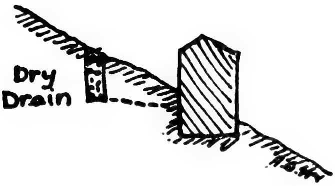


Fig. 8.

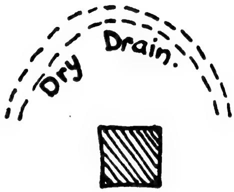


Fig. 9.

Figs. 8 and 9.—Diverting Down-hill Flow of Water, Section and Plan.

any direction, and he may discover that immediately below the impervious strata there is a highly pervious subsoil; he then digs an absorption well, and the ream water being led into this, is absorbed by the pervious strata. (G. D.

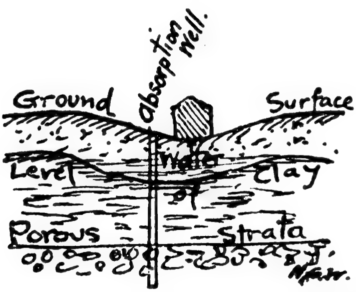


Fig. 10.—Obstructed Rain-water Bed to Porous Strata.

Dempsey, "Drainage of Districts and Lands"; also Dr. Ransome, "Soils and Sites," p. 4.)

Other methods may suggest themselves, among which is the raising of the subsoil water to a sufficient height by mechanical means, there being many appliances for this purpose. Wind-pumps, steam-pumps, compressed air-pumps,

Shone's pneumatic ejector, Adams' sewage and water lift, among many others, may be mentioned.

A method of avoiding subsoil air and water is to build the house on a series of arches, as shown in Fig. 11, so that it may be clear above the surface of the ground. Yet another method is to lay a bed of concrete, make the excavation larger each way than the house, and construct concrete retaining walls (see Fig. 12).

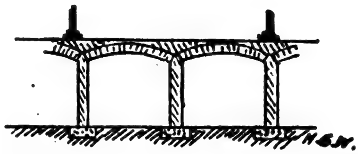


Fig. 11.—Foundation laid on Arches to avoid Subsoil Air and Water.

From what has already been said, it will be seen that from a hygienic point of view the M.B.L. No. 11 is an exceedingly wise provision. The jerry-builder may grumble at the cost; the average person may be blindly indifferent;

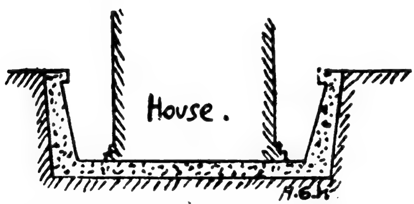


Fig. 12.—Foundation laid on Concrete Bed to avoid Subsoil Air and Water.

but the motto of the sanitarian is, "The health of the people is the highest law."

In towns where the "concrete bed" bye-law does not exist, there ought, at all events, to be regulations furthering the same object. Where a house has cellars, they should be paved with impervious material—either with concrete or with flags jointed with cement. Where the house is not cellared, and has boarded floors, there should be a space of at least 18 in. below the joists, and this space should be

ventilated by means of two or more large air-grids (9 in. by 6 in.) on opposite sides; and, wherever practicable, an extra flue should be carried up in the chimney breast and connected to this space, so as to form an exhaust ventilation shaft (see Fig. 13). The floor boards should be rebated or grooved and tongued, so as to prevent the passage of foul air and also cold air from the air grids. The L.G.B. have the following M.B.L. on this point:

M.B.L. No. 55: "Every person who shall erect a new domestic building shall so construct every room which shall be situated in the lowest storey of such building, and shall

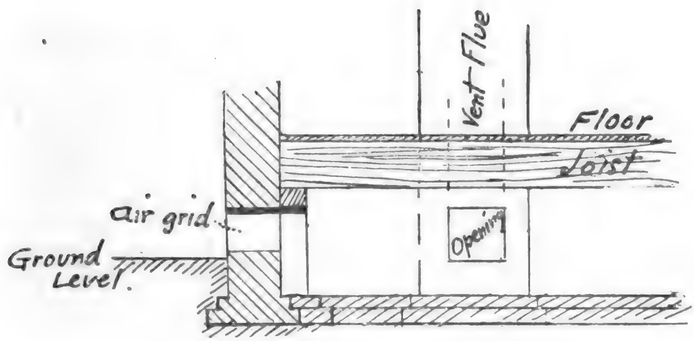


Fig. 13.—Ventilation of Space under Bottom Floor.

be provided with a boarded floor, that there shall be, for the purpose of ventilation, between the under side of every joist on which such floor may be laid, and the upper surface of the asphalt or concrete with which, in pursuance of the bye-law in that behalf, the ground surface or site of such building may be covered, a clear space of 3 in. at the least in every part, and he shall cause such space to be thoroughly ventilated by means of suitable and sufficient air-bricks, or by some other effectual method. Provided that the foregoing requirement shall not apply in the case of a room provided with a solid floor composed of boards, planks, or wood blocks, laid or bedded directly upon concrete or other similar dry and impervious foundation."

There are two other M.B.L. (Nos. 12 and 13) which will

be of very great use to those towns adopting them. They give the Local Authority power to prohibit the erection of dwelling-houses, upon excavated sites, low-lying land, or land liable to be flooded, until the site has been filled up to a certain level above ordnance datum* with clean material, so as to form a "stable and healthy substratum" for the foundation of such building.

The following is the text of these bye-laws :—

M.B.L. No. 12 : "In every case where the intended site of a new building may have been or may have formed part of a clay pit, or where, by reason of excavation and the removal of earth, gravel, stones, or other materials from such site, the whole or any part of the surface thereof may be at such a depth below the level of the surface of the ground immediately surrounding and adjoining such site as may render the elevation of the whole or part of the existing surface of such site necessary for the prevention of damp in any part of any building to be erected thereon : A person shall not construct any foundation of a new building upon such site or upon such part thereof as, for the purpose aforesaid, may require elevation, unless and until there shall have been properly deposited thereon a layer or layers of sound and suitable material sufficient to elevate such site or such part thereof to an adequate height, and to form a stable and healthy substratum for such foundation."

M.B.L. No. 13 : "In every case where the intended site of a new building may be [within an area bounded by] [at a height less than ft., above ordnance datum] (*here insert, alternatively, the height below which, or a description of the boundaries of the area to which, the following requirement is to apply*), a person shall not construct any foundation of such building unless and until there shall have been properly deposited upon the site a layer or layers of sound and suitable material sufficient to elevate such site to a height at least ft. above the ordnance datum."

* The ordnance datum is an imaginary horizontal plane extending over the whole country at the same height as the mean sea level at Liverpool. This was fixed by the Surveyors of the Ordnance Department, and the levels of districts are marked on the ordnance maps as being so many feet above the ordnance datum or above the mean sea level at Liverpool.

Coming to questions about the healthiness of a site itself, it is found that the structure and composition of the underlying geological strata are of less importance than is generally supposed. Examining the data on this head given by Dr. Parkes, and confirmed by other sanitarians, it appears that there are very few positively unhealthy grounds, provided they are natural and not artificially laid down, and are not polluted from some external source. Much depends, however, on the method of using the site, the position of the house, etc.

Granitic, metamorphic, and trap rocks, as well as the slates, are generally healthy, as these usually slope considerably, so that water runs off readily, and they are very impermeable; but when they have begun to disintegrate or decompose, they pass into a sort of loam, occasionally become permeated with fungus, and are supposed to be unhealthy.

Limestones and hard calcareous rocks generally form healthy sites, when not overlaid by a marsh, and not water-logged. A word of caution is necessary on this latter point: the ground-water level in such rocks as the limestones varies with the rainfall of the district; and what at one period of the year is an apparently dry site, may become water-logged for months together.

The sandstones, sands, and gravel are always healthy, except when low-lying and water-logged. Clays, loam, dense marls, and alluvial soils, generally damp in their nature, are to be regarded with suspicion, and should be carefully and discreetly dealt with in the ways already suggested. Made soils have been fully discussed (pp. 15–17). Probably the most healthy site for building purposes is on a dry gravel soil of moderate thickness and in an elevated position.

Captain Galton, in his work on "Healthy Dwellings," gives instances showing the sanitary importance of the situation of a house. One of these has reference to the outbreak of fever among soldiers in the Crimea. Fig. 14 shows the slope of the ground falling towards the plain of Balaclava. The foundations are rock below and above, traversed by a belt of clay and shale. The 79th Highlanders were placed on the clay, and as the material was soft, their huts were placed on terraces cut out of the hillside, and were thus

embedded in the ground; and the floors, consequently, were always damp. There was no roof ventilation. This regiment had half the men down with fever. The 42nd Highlanders were placed on the rock, and as it was hard, they did not cut into the rock, but preferred building their huts on pro-

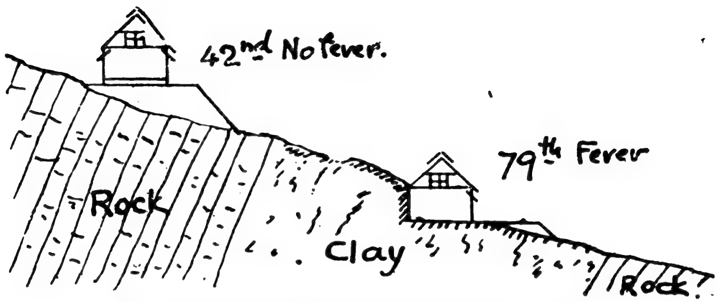


Fig. 14.—Good and Bad Positions of Soldiers' Huts.

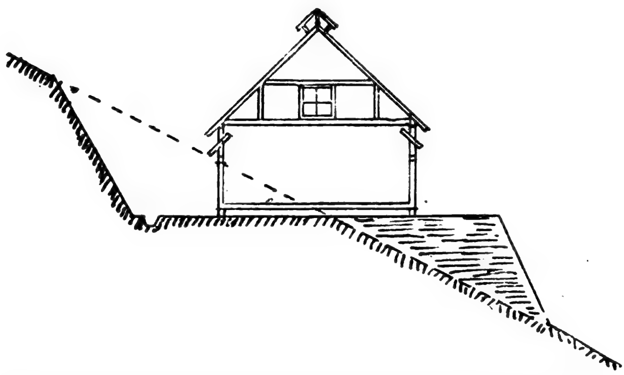


Fig. 15.—Improved Construction and Position of Lower Huts.

jecting terraces, so that they were quite dry, and air circulated freely round. This regiment did not suffer from fever. The huts on the clay were subsequently altered as shown at Fig. 15, so as to allow free circulation of air. Drainage and roof ventilation were provided as shown, and fever no longer prevailed.

The story emphasises the importance of making a geological examination of a site, wherever the inspector is called in to inquire into the cause of any mysterious outbreak of disease. The whole evidence before us shows the necessity in many cases; and it also shows that a healthy site may be only the space of a few feet from an unhealthy site (see also Fig. 16). On the other hand, the inspector must beware of becoming a crank on this one point of his examination, or he may blame the soil for illnesses with which it has nothing whatever to do.

Fig. 16.—Healthy and Unhealthy Sites for Houses.

Messrs. Miers & Crosskey, in their valuable little work, "The Soil in Relation to Health," cite a case in which the soil was hastily blamed for illness that was really attributable to defective sanitary engineering: "A family who for many years had lived in a town situated upon a deep bed of gravel, moved into a house built on the clay. On taking up their new residence, nearly all the family suffered from sore throats of a septic nature, which were at once attributed to the 'horrid damp clay.' It was found, however, on investigation, that the ventilating shaft to the soil-pipe opened just underneath one of the best bedroom windows, and the waste-pipe to the bath was untrapped, and joined the soil-pipe. When these and other defects were remedied, there was no further trouble from sore throats."

CHAPTER III.

MATERIALS OF CONSTRUCTION.

THE materials to be used in the structure of walls are referred to in Bye-law No. 14, which reads as follows :—

M.B.L. No. 14 : "Every person who shall erect a new building shall, except in such cases as are hereinafter specified, cause the external and party walls to be constructed of good bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together : (i) With good mortar compounded of good lime and clean sharp sand, or other suitable material ; or (ii) with good cement ; or (iii) with good cement mixed with clean sharp sand."

The materials, then, of which walls may be constructed are "bricks, stone, or other hard and incombustible materials" ; the latter may be taken to include terra-cotta, tiles, concrete, and other artificial stones. The healthiness of these materials depends upon their non-absorbent qualities. They must not be absorbent of moisture in the form of rain, or the dampness will be transmitted through to the interior ; they must not be porous, or the external air will penetrate either by its own force or owing to the suction of the chimney.

A good brick should be hard, so that it may be able to stand the knocking about before, and the pressure to which it will be subjected after, it is built into the structure ; should be well burnt, so that it may withstand damp, which is terribly destructive to ill-burnt bricks ; should be truly square and regular in shape, with clean sharp arrises ; when struck should give out a clear metallic ringing sound ; and when broken, should break clear, without falling to pieces as it were. The size of bricks varies in different parts of the country. In London users prefer them $8\frac{3}{4}$ in. by $4\frac{1}{2}$ in. by $2\frac{3}{4}$ in. thick ; in Lancashire, 9 in. by $4\frac{1}{2}$ in. by 3 in. ; and some makers send them out even thicker than 3 in. Their weight is about $7\frac{3}{4}$ lb. each, or 110 lb. to the cubic foot. Machine-made bricks are heavier.

As regards porosity, in 1868 the Manchester Society of Architects tested experimentally a large number of different kinds of bricks, taken indiscriminately from buildings then in progress and from brickyards. The results of these experiments are thus summarised: "Bricks should not absorb when saturated above 20 per cent. of their bulk of water, and should absorb it reluctantly, and part with it with facility at ordinary temperatures." Now the wall of a cottage 16 ft. long, 8 ft. high, and 9 in. thick will contain 96 cub. ft.; and supposing the wall to absorb 20 per cent. of its bulk, as stated above, it would hold in its pores 19 cub. ft., or nearly 120 gal. of water! Hence the necessity for adopting non-porous materials for walls, and the stipulation for damp-proof courses, and the advisability of cavity walls.

Terra-cotta and tiles may be considered as bricks in other forms, and of a less porous nature. Terra-cotta has a glazed surface, which to some extent throws off the water; tiles are nailed to the surface of the wall, hence there is a slight cavity which prevents the transmission of absorbed water.

For ordinary buildings stone is only used in a "stone" country; and then the local stone is used without reference to its porosity or fitness in other respects. The stone being cheap in its unworked state, walls are built thicker than the minimum necessary for hygienic construction, as it is cheaper to build thick walls than to expend time and labour in cutting the stones to the smaller size. More care should be taken in bonding the stones together than in a brick wall; numerous "through" stones should be provided in rubble work, and the small spaces between the largest stones should be filled with pieces of stone as large as can be placed there, for the wall is to be of stone, not of mortar. Great care also should be taken that the stone, of which most of that used for building purposes is stratified or laminated like the leaves of a book, shall be placed on what is called its natural bed—that is, with the strata or leaves lying horizontally, as it was formed in the quarry. If this is not done the action of the air in most cases will cause the laminæ or strata to separate or fall away. Instances of this may be seen in buildings where certain stones have been, as it were, eaten away for some inches in depth. Stones should be marked on the top side at the quarry as a guide.

There are very few parts of the country where there is not an ample supply of clay suitable for brickmaking, or of stone; hence in not many places is concrete building anything but an experiment. Cases may arise, however, where a building has to be erected in concrete, in which case the following points, among others, will need attention: (*a*) The portland cement should be of the best quality in all respects. (*b*) The aggregate should consist of hard gravel, broken stone, broken bricks, burnt clay ballast, or other suitable material, small enough to pass through a 2-in. ring; the sand should be clean and sharp. (*c*) The proportions should be 1 part cement, 2 parts sand, 4 parts aggregate. (*d*) Proper gauge-boxes should be provided for measuring the various materials; no guesswork or rule-of-thumb should be allowed on any pretext. (*e*) The work should be carried up in layers of equal height. (*f*) Provided the foregoing conditions are duly observed, the walls need not be built any thicker than if brickwork were used. Of course, proper templates and framework should be carefully fixed to confine the concrete until it has set. This will need considerable care and ingenuity.

The second portion of the bye-law now claims attention. It will be seen that while good lime is specified, there is nothing to show what is meant by good lime, nor how it is to be distinguished from bad lime; good mortar is also required, but the constituents of good mortar are not specified. In a Note on the subject, however, the following modifications are suggested by the annotator :—

"(*a*) With good mortar, compounded of freshly burned lime and clean, sharp sand or grit, without earthy matter, in the proportion of 1 of lime to 3 of sand or grit; or,

"(*b*) With good portland cement or other good cement of equal quality mixed with clean, sharp sand or grit in the proportion of 1 of cement to 4 of sand or grit:

"Provided that in either case hard burnt ballast or broken brick may be substituted for sand or grit if clean and not mixed with any old mortar, and provided that such hard ballast or broken brick be properly mixed with lime or cement in a mortar-mill."

Where this modification is adopted, bye-law No. 15 should be similarly altered.

The sand should be clean sharp river or pit sand; if sea sand is used, it should be well washed to remove the saltness, otherwise the mortar will not set, or, if it does, it will be hygrometrical—that is, in damp weather it will become wet, owing to the salt in it, and remain so until the atmosphere dries, thus acting as a perpetual barometer. The sand should be clean, as any admixture of clay, soil, slime, or other impurity will kill much of the lime, and the mortar will disintegrate or become rotten within a few weeks or months after setting, even if it sets at all. A simple test is to rub some of the sand in the palm of the hand. If it is not clean it will leave a stain, the depth of the stain indicating the amount of impurity. The sand should also be sharp or gritty; seen through a microscope each grain should be all angles, like a piece of crystallised sugar-candy, and not rounded like lumps of gum arabic.

There are many available substitutes for sand, but they must all be crushed under rollers in a mill until they are similar in size to grains of sand. Among them may be noted crushed stone, burnt clay or ballast (but it must be thoroughly burnt), smithy ashes, furnace slag and scoriæ, and anything of similar nature which is gritty, hard, clean, and used with discretion. Other substitutes have been used by the jerry-builder, such as road sweepings, garden soil, ashpit refuse, etc.; the sanitary inspector will have to keep his eyes open on this point, especially in those towns where the bye-law is indefinite.

Limes are divisible into three classes—(1) rich or pure or fat lime; (2) poor or impure or meagre lime; and (3) hydraulic lime. Rich lime is burnt from stones that consist almost entirely of carbonate of lime (calcium carbonate); other substances may be present to the extent of 10 per cent. The calcium carbonate or limestone is burnt to expel the water and carbonic acid gas it contains, the product being calcium oxide; when the calcium oxide is slaked by addition of water it becomes calcium hydrate; when calcium hydrate is mixed with sand—that is, made into mortar—and the mortar placed in position between bricks, etc., it absorbs carbonic acid gas from the atmosphere, and once more becomes calcium carbonate or limestone. This rich lime is unsuitable for mortar for external walls, and

should not be used in exposed places, as it is soluble in water, and will not set in damp situations. It is, however, valuable for internal plastering. Poor lime has all the disadvantages of rich lime, with others added; it is rich lime very much adulterated, and should never be used.

Hydraulic lime will set in damp situations without drying (hence its name), and becomes harder with age. The most important hydraulic limes owe their peculiar quality to a certain proportion of clay being mixed with or forming part of the raw stone. After burning, the lumps are broken small, and slaked with a minimum quantity of water. The most useful hydraulic limes are those obtained from blue lias limestone, which is found in many parts of England.

There are several important provisions in M.B.L. No. 14. They read as follows:—

"(*a*) That such person may construct any external wall of such building as a hollow wall, if such wall be constructed in accordance with the following rules: (i) The inner and outer parts of the wall shall be separated by a cavity which shall throughout be of a width not exceeding 2½ in., and shall be properly drained and ventilated. (ii) The inner and outer parts of the wall shall be securely tied together with suitable bonding ties of adequate strength, formed of galvanised iron, of iron tarred and sanded, or of glazed stoneware. Such ties shall be placed at distances apart not exceeding 3 ft. horizontally and 18 in. vertically. (iii) The thickness of each part of the wall shall throughout be not less than 4½ in. (iv) The aggregate thickness of the two parts, excluding the width of the cavity, shall throughout be not less than the minimum thickness prescribed by the bye-law in that behalf for an external wall of the same height and length, and belonging to the same class of building as that to which the hollow wall belongs. (v) All woodwork which may be intended to form the head of a door frame or window frame, or lintel, or other similar structure, and may be inserted in the wall so as to project into or extend across the intervening cavity, shall be covered throughout on the upper side thereof with a layer of sheet lead, or other suitable material impervious to moisture, in such a manner as effectually to protect such woodwork from any moisture that may enter the cavity.

"(*b*) That where a new building intended for use as a dwelling-house shall be distant not less than 15 ft. from any adjoining building not being in the same curtilage, the person erecting such new building may construct its external walls of timber-framing, subject to compliance with the following conditions, that is to say :—(i) The timber-framing shall be properly put together, and the spaces between the timbers shall be filled in completely with brickwork or other solid and incombustible material. (ii) A thickness of at least 4½ in. of brickwork or other solid and incombustible material shall be placed at the back of every portion of timber.

"(*c*) That where a new building forms or is intended to form part of a block of new buildings which shall be intended for use as dwelling-houses, and shall not exceed three in number, and each of which shall be distant not less than 15 ft. from any adjoining building not being in the same curtilage, and not forming part of the same block, the person erecting such new building may construct its external walls of timber-framing, subject to compliance with the following conditions, that is to say :—(i) The several buildings shall be separated by party walls, each of which shall be constructed in accordance with the requirements of the bye-laws in that behalf, and shall project at least 1 in. in front of any timber-framing in any adjoining external wall. (ii) The timber-framing shall be properly put together, and the spaces between the timbers shall be filled in completely with brickwork or other solid and incombustible material. (iii) A thickness of at least 4½ in. of brickwork or other solid and incombustible material shall be placed at the back of every portion of timber.

"(*d*) That where a new building which comprises *two* or more storeys forms, or is intended to form, part of a block of new buildings which shall be intended for use as dwelling-houses, and shall not exceed *three* in number, and each of which shall be distant not less than 15 ft. from any other building, not being in the same curtilage and not forming part of the same block, the person erecting such new building may construct the external walls of the topmost storey, or if the building comprises more than *two* storeys, of the topmost *two* storeys, of timber-framing covered with tiles,

subject to compliance with the following conditions, that is to say—(i) The timber-framing shall be properly put together, with sufficient braces, ties, plates, and sills. (ii) So much of any external wall as is below that portion which

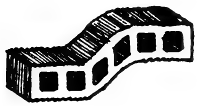


Fig. 17.

Fig. 17.—Jennings' Old Pattern Bonding Brick.

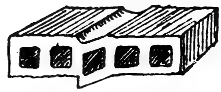


Fig. 18.

Fig. 18.—Jennings' 1891 Bonding Brick.

may be of timber-framing covered with tiles shall be constructed of the same thickness, and in other respects subject to the same conditions, as would be applicable if the wall had been constructed throughout its whole height of good

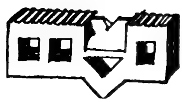


Fig. 19.

Fig. 19.—Doulton's Bonding Brick.

Fig. 20.

Fig. 20.—Wrought-iron Bonding Tie.

bricks, stone, or other hard and incombustible materials. (iii) Every party wall in any such block of buildings shall be carried out at least to the external face of any timber-framing in any adjoining external return wall.

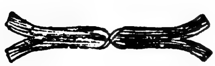


Fig. 21.

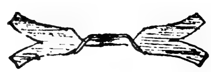


Fig. 22.

Figs. 21, and 22.—Wrought-iron Bonding Ties.

One of the best bonding ties for cavities is a Jennings bonding brick. The old pattern (Fig. 17) was defective, in that it only fitted courses of a certain gauge, and had to be tilted one way or the other if the course varied from the thickness of the bonding brick. In the 1891 pattern

(Fig. 18) this defect has been remedied. Equally good is Messrs. Doulton's bonding brick (Fig. 19). Wrought-iron cramps of various shapes may be used (see Figs. 20, 21, and 22). The M.B.L. allows the thickness of each half-wall to be 4½ in. There is a general consensus of opinion that one of the portions of the wall should be 9 in. thick, though there is not the same agreement as to whether the thick portion or the thin portion should be placed on the outside. As a rule, it is better for the 9-in. portion to be outside and the 4½-in. portion inside. The stipulation for a sheet of lead on the upper surface of any beam will be better understood by reference to Fig. 23.

In building a cavity wall the bricklayer should lay a

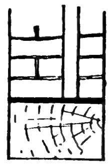


Fig. 23.—Section of Lead-covered Beam.

lath along the bottom of the cavity to catch the droppings of mortar; and when he reaches the level of the bonding brick, he should carefully draw up the lath, and lay it on top of the bonding brick until the next is reached. A cavity, in addition to resisting damp, tends to keep the house cooler in summer and warmer in winter, the air in the cavity acting like a cushion to prevent the transmission of heat. Many objections have been made to the construction of cavities: they form runs for vermin, they transmit noises from one part of the building to another, rattling noises are heard from bits of mortar dropping, and if sewer gas finds its way into the cavity it may be transmitted all over the house, and filter through all the walls.

With a view of obviating these annoyances and nuisances, many sanitary engineers construct the cavity only about ½ in. in width, and pour in melted asphalt. This being done every six courses, the wall becomes a solid homogeneous mass—damp-proof and much stronger than an ordinary wall (see Figs. 24 and 25).

The next three M.B.L. explain themselves. No. 15 requires that cross-walls shall be of the same good materials as the external walls; No. 16 stipulates that all walls shall be built true and plumb; and No. 17 insists that walls joining one another shall be bonded together.

M.B.L. No. 15: "Every person who shall erect a new building shall construct every cross-wall, which, in pursuance of the bye-law in that behalf, may, as a return wall, be deemed a means of determining the length of any external wall or party-wall of such building, of good bricks, stone, or other hard and incombustible materials properly bonded and solidly put together:—(i) With good mortar

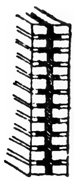


Fig. 24.

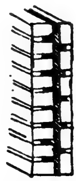


Fig. 25.

Figs. 24 and 25.—Hollow-built Walls Filled with Asphalt.

compounded of good lime and clean sharp sand, or other suitable material; or (ii) with good cement; or (iii) with good cement mixed with clean sharp sand."

M.B.L. No. 16: "A person who shall erect a new building shall not construct any wall of such building so that any part of such wall, not being a part properly corbelled out or supported, or a projection intended solely for the purposes of architectural ornament, shall overhang any part beneath it."

M.B.L. No. 17: "Every person who shall erect a new building shall cause every wall of such building which may be built at an angle with another wall to be properly bonded therewith."

CHAPTER IV.

FOOTINGS, FOUNDATIONS, AND DAMP-PROOF COURSES.

THE next M.B.L. deals with the footings. The object of footings is, as the name implies, to give the wall something to stand upon; and it may be remarked that footings are absolutely necessary wherever the ground is of a softer nature than the material of which the wall itself is composed. The M.B.L. on this portion of the subject is as follows:—

M.B.L. No. 18: "Every person who shall erect a new

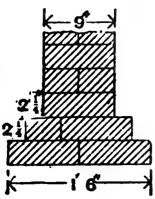


Fig. 26.—Footings for 9-in. Wall.

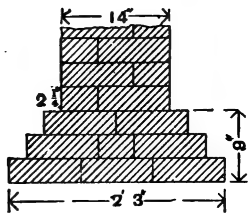


Fig. 27.—Footings for 14-in. Wall.

building shall construct every wall of such building so as to rest upon proper footings, or upon a sufficient bressummer.

"He shall cause the projection at the widest part of the footings (if any) of every wall, on each side of such wall, to be at least equal to one half of the thickness of such wall at its base, unless an adjoining wall interferes, in which case the projection may be omitted where that wall adjoins.

"He shall also cause the diminution of the footings to be in regular offsets, or in one offset at the top of the footings, and he shall cause the height from the bottom of the footings to the base of the wall to be at least equal to two-thirds of the thickness of the wall at its base."

Sketches of the footings of the walls of ordinary thickness,

drawn as described in this regulation, are given in Figs. 26, 27, and 28. From the dimensions shown on these figures it will be seen that the total breadth of the footings is twice the thickness of the wall. Where there is an adjacent wall the footings on that side are not necessary (see Fig. 29). Footings have been sometimes formed solid—that is, without the set-offs of 2¼ in. each, as shown in Fig. 30; and from this fact it is argued that when the ground is harder than the wall, footings are unnecessary.

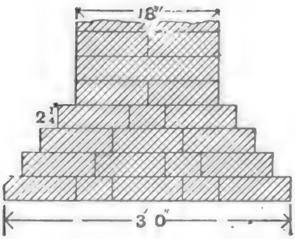


Fig. 28.—Footings for 18-in. Wall.

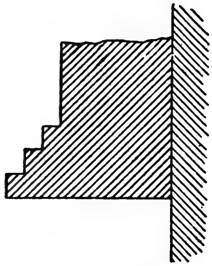


Fig. 29.—Footings on one Side of Wall only.

When a building has been constructed with inadequate footings, and it becomes necessary to increase their width, this can be done by carefully excavating in short lengths, and constructing wider footings in cement mortar, properly bonded into the existing work (see Fig. 31); each side of the wall being done at different times.

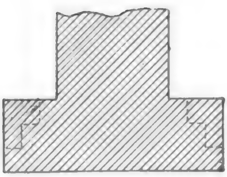


Fig. 30.—Footings without Set-offs.

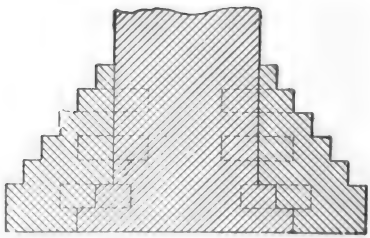


Fig. 31.—Footings added to Existing Work.

It often happens that the soil upon which a building is

to be erected is too soft to receive the footings, a circumstance for which the next bye-law makes the following provision:—

M.B.L. No. 19: "Every person who shall erect a new building shall cause the footings (if any) of every wall of such building to rest on the solid ground, or upon a sufficient thickness of good concrete, or upon some solid and sufficient substructure, as a foundation."

Foundations are divided into classes, according to the nature of the ground and the weight of the building. Among soft grounds are classed peat, quicksand, loam, surface soil or humus, and others of a similar nature. Among the medium grounds are the damp sands, loose gravels, wet clays, shales, sham rocks. The hard grounds comprise the rocks, dense dry clays, and close dry gravels. The method of preparing

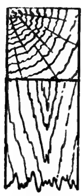


Fig. 32.—Pile with Timber Crosshead.

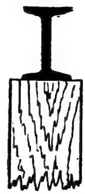


Fig. 33.—Pile with Steel Crosshead.

foundations upon these various materials depends chiefly upon the weight of the proposed building.

Heavy building on soft ground presents the most difficult problem, and the subject is so large that it is here only possible to indicate the more usual methods of treatment. When it is necessary to erect a heavy building upon soft ground, more solid ground underneath must by some means be reached; and there are two courses open—either to excavate the full depth, or to drive piles.

If the soft ground is of but moderate depth—say less than 20 ft.—trenches may be cut under the walls down to the solid, and filled up with concrete. If the soft ground is much less than 20 ft., it may be excavated entirely, and either used as a cellar or filled up with concrete or hard, dry material.

If the soft ground is more than 20 ft. in depth, piles

must be used. The term piles is here employed in the very broadest sense, and may be taken as including pillars of timber, iron, steel, concrete, or brickwork. An ordinary timber or iron pile needs no description. It must be sufficiently

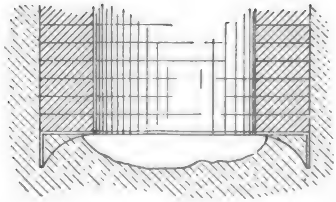


Fig. 34.—Brick Pillar on Cutting Ring.

long to reach the solid ground (timber piles may be obtained up to 70 ft. in length), and the piles must be sufficiently numerous to carry the weight. Timber piles should be cut off at the ground-water level. Across the tops should be

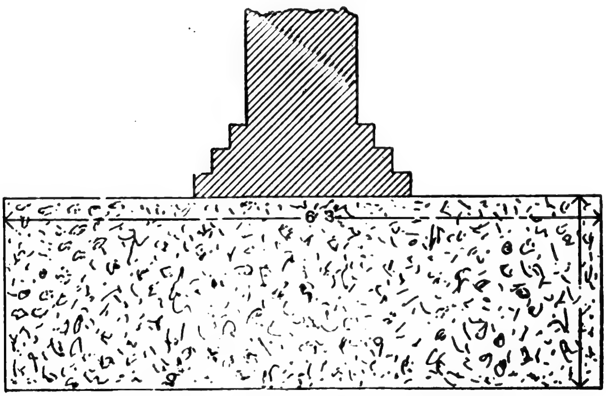


Fig. 35.—Concrete Foundation in Soft Ground.

laid crossheads either of timber (Fig. 32) or of steel (Fig. 33); and upon these a bed of concrete covering the whole site should be laid.

Concrete or brick pillars may either be excavated for and built solid; or may be built on a cutting ring (Fig. 34)

and forced down, the material being taken from the inside, and the space afterwards filled with concrete. The former method will serve when there is little or no water to contend with; the latter when it is cheaper to use a grab than to pump. A third course is possible. In Chicago there are portions of the town where a solid bottom cannot be reached, the subsoil growing softer as excavation goes deeper. In such cases very little excavating is done, but an exceedingly broad foundation, of concrete bound together and interlaced with steel girders, is formed, and this practically floats upon the liquid foundation. On this the buildings are erected, some of them being more than ten storeys high.

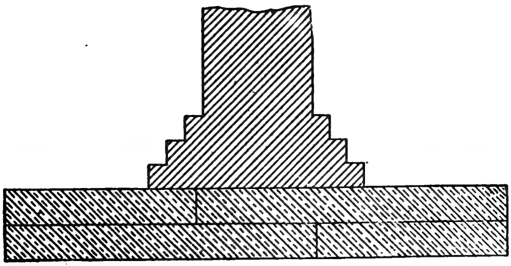


Fig. 36.—Wall Foundation Formed by Flagstones.

In the case of light buildings on soft ground it is not necessary to find a solid bottom; indeed, if the uppermost stratum is fairly firm, while the underneath strata are soft, it is better not to excavate more than is absolutely necessary.

A broad platform of concrete (Fig. 35), 6 ft. or 9 ft. wide and 2 ft. or 3 ft. thick—the thickness varying according to the softness of the soil—will be quite ample; or, if the soil is fairly hard, two thicknesses of strong rough flags (Fig. 36) will suffice, with the proviso that the weight of the building should be approximately equal throughout. If one portion of the building consists of three storeys, and another portion of only one storey, there will be unequal settlement, and large cracks will become manifest. Unless the building be of equally distributed weight throughout, the concrete founda tion must be sufficiently large to act as a beam, and to bear the unequal load without breaking.

It is possible to spend an enormous amount of money on foundations in bad ground—sometimes more than the whole value of the building itself. On the other hand, by unwise parsimony in preparing the foundations, it is quite possible to ruin a costly building for ever.

Very great care is necessary in determining how much or how little foundation should be provided for heavy buildings on medium ground. There is always a natural temptation to consider the ground good enough. With damp sands and wet clays it might be thought sufficient to lay a broad foundation of concrete. Here, however, there is great danger that water abstracted from underneath, thereby allowing shrinkage of the subsoil, will lead to equal or unequal settlement. An adjacent railway cutting or well may lead to this abstraction of water, and the consequences would be disastrous. The shales are also dangerous, owing to the tendency to slide under pressure; the cutting of a sewer in the street, or even for the building in course of erection, or an excavation next door may lead to this. No decision should be arrived at, even when the excavation has been got out as far as the footing level, without two or more deep trial holes sunk several feet farther.

Even when a bed of rock has been reached it is not safe to use that until a boring has been driven down some distance; for in a multitude of cases, and especially in alluvial soils, the rock may be only 2 in. or 3 in. thick, overlying a bed of sand or quicksand, while the real rock is some feet deeper. Mr. John Holden, F.R.I.B.A., found a case of this sort in the foundations of the Grosvenor Hotel (Holden: "Foundations and Materials," p. 56). In another case a trial hole was dug for the purposes of ascertaining strata and preparing plans and quantities. The trial hole was continued until rock was reached. After the contract had been signed the excavation was got out, and it was found that the bed of rock, on which it was intended to erect a lofty chimney, was only 2 in. thick; the excavation had to be continued 10 ft. or 11 ft. deeper, and the extra cost was between £200 and £300. As before remarked, a lot of money may be squandered from want of wisdom, whilst undue parsimony may be ruinous from want of discretion.

Light buildings on medium ground, and light and heavy

buildings on hard ground, need no special description as to their foundations. A little wisdom combined with sufficient discretion will indicate the right sort of foundation.

On the subject of damp-proof courses the M.B.L. of the L.G.B. is very strict, but not more strict than the importance of the matter demands, considering the porous nature of brickwork and its power of absorbing and transmitting water by capillary attraction. The bye-law reads thus :—

M.B.L. No. 20 : "Every person who shall erect a new public building or a new domestic building shall cause every wall of such building to have a proper damp-proof course of sheet-lead, asphalt, or slates laid in cement, or of other not less durable material impervious to moisture, beneath the level of the lowest floor, and at a height of not less than 6 in. above the surface of the ground adjoining such wall. Provided always that where any part of a floor of the lowest storey of such building, not being a cellar adapted and intended to be used for storage purposes only, shall be intended to be below the level of the surface of the ground immediately adjoining the exterior of such storey, and so that the ground will be in contact with the exterior of any wall, he shall cause such storey, or such part thereof as will be so in contact, to be constructed with walls impervious to moisture or with hollow walls, constructed in accordance with the requirements of the bye-law in that behalf, and extending from the base of such walls to a height of 6 in. at least above the surface of the ground immediately adjoining the exterior of such storey. He shall also cause a proper damp-proof course of sheet-lead, asphalt, or slates laid in cement, or of other not less durable material impervious to moisture, to be inserted in every such wall at the base of such wall, and likewise at a height of 6 in. above the surface of the ground immediately adjoining."

It will be seen that the L.G.B. appear to have considered all possible contingencies—namely, floor above the external ground, at the level of the ground, and when the floor is below the external ground level.

The illustrations to the M.B.L. No. 20 are reproduced by permission of Messrs. Knight and Co. Fig. 37 shows the position of the damp-proof course when the floor is above the external ground ; Fig. 38 when the floor is at the level

of the external ground; and Fig. 39 when the floor is below the external ground level. D P signifies damp-proof course; G, ground; FL, floor; J, joist; C, concrete; CAV., cavity; W, wall-plate, and F, flag.

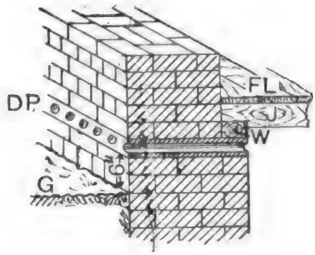


Fig. 37.—Damp-proof Course when Floor is above Ground Level.

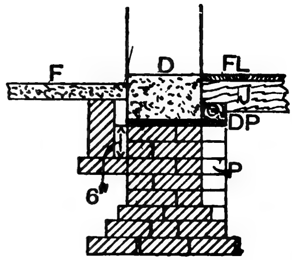


Fig. 38.—Damp-proof Course when Floor is Level with Ground.

As to the material to be used, the best, though the most costly, is that first mentioned, namely, sheet lead. This should be of the thickness known as "4-lb. lead"—that is,

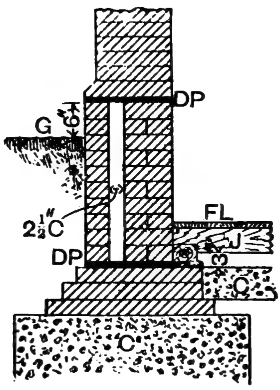


Fig. 39.—Damp-proof Course when Floor is below Ground Level.

weighing 4 lb. to each superficial square foot. Lead has the following advantages:—(*a*) It is very effectual; (*b*) it is not squeezed out by pressure; (*c*) it gives to the inequalities of the bricks; (*d*) it is not injured by unequal settlement.

Staffordshire blue bricks set in portland cement form a good damp-proof course. These bricks are practically non-porous, and, if the joints are well filled with cement, the course is quite effectual. Mr. John Taylor, in 1859, devised a course formed of two vitrified tiles, channel-shaped, and of length equal to the thickness of the wall (Fig. 40). His later pattern is a single tile with grooves on the outside faces (see Fig. 41). Other tiles on similar principles are

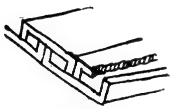


Fig. 40.—Taylor's Original Damp-proof Course.

Fig. 41.—Taylor's Improved Damp-proof Course Tile.

manufactured by Messrs. Doulton (Fig. 42), Broomhall (Fig. 43), and others.

Slates set in portland cement are also used as a damp-proof course. To be effectual the laying must be done with the greatest care; otherwise, by the unequal pressure, the slates are sure to crack and break. There should be two courses of slate, with cement below, between, and above, and the slates should break joint.

The material generally used for a damp-proof course is asphalt, its quality depending very much upon the amount

Fig. 42.—Doulton's Damp-proof Course Tile.

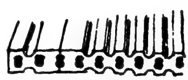


Fig. 43.—Broomhall's Damp-proof Course Tile.

of money the owner is spending upon the building. The best natural asphalt, the seyssel, or limmer rock (an excellent material), is at one end of the line; at the other end is the jerry-builder's asphalt, formed of coal-tar, pitch, and sand. Between these two are many grades of asphalt damp-proof courses, the misfortune being the absence of a legal definition as to the real substance intended under the designation "asphalt." To meet the difficulties that may arise in this

respect, the clause has been modified in some districts as follows :

"Every person who shall erect a new building shall cause every wall of such building to have a proper damp-course of sheet lead, mineral asphalt, or slates laid in cement, or of other suitable hard-setting and durable material, not being tarred felt, and impervious to moisture, beneath the level of the lowest floor, and at a height of not less than 6 in. above the surface of the ground adjoining such wall."

Another method of keeping out the dampness of the external ground is by a coating of asphalt on the outer face of the brickwork. This is adopted as an ordinary practice

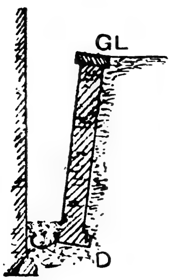


Fig. 44.

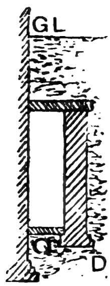


Fig. 45.

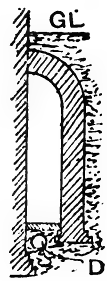


Fig. 46.

Figs. 44, 45, and 46.—Examples of Dry Areas for Keeping out Damp.

by sanitary engineers. A Local Authority has, however, no means of enforcing it in its district. The P.H.A., 1875, gives power to make bye-laws "with respect to the structure of walls, foundations, etc."; but a coat of asphalt on the outer face of a wall is not an integral part of the *structure* of the wall; and therefore no bye-law can be made to enforce such a desirable protection against damp.

Sanitary engineers also attain the same end by constructing external cavities or dry areas. There are many ways of constructing these, three examples being shown at Figs. 44, 45, and 46, where G L is the ground level and D the drain.

In view of the foregoing provisions, all made with the view of keeping out damp, it may be useful to bear in mind a simple test for finding out whether a room or a house is too damp to be healthy. The method is recommended by

Dr. Paolo Mantezza, and although rough-and-ready and somewhat superficial, is easy to carry out, and accurate enough for all practical purposes. "It is based on the property which certain bodies have of absorbing the water contained in the air—as lime, for instance. Take 500 grammes of lime, newly burned, not slaked or pulverised; place it on a plate in the room to be examined for twenty-four hours, with the doors and windows closed; at the end of this time weigh it, and if the weight has not increased more than a gramme, the room may be declared inhabitable. If the weight has increased 5 grammes or more the room cannot be inhabited without danger. The proper degree of hygrometry oscillates between 1 gramme and 5 grammes more or less for inhabited places. This test, which is not mathematical, of course, can be applied suitably always to rooms of ordinary dimensions. It would not be suitable for very large or very small rooms."

The law is not very precise, though quite clear, with regard to the action of the sanitary inspector in the case of damp houses. § 91 of the P.H.A., 1875, says: " . . . Any premises in such a state as to be a nuisance or injurious to health . . . shall be deemed to be nuisances liable to be dealt with summarily in manner provided by this Act." Here are two separate grounds on which a damp house may be dealt with: First, is it in such a condition as to be a nuisance? Secondly, is it in such a condition as to be injurious to health? The Act, however, does not give a definition to the term nuisance, and this has provided much work for the lawyers. Mr. Justice Blackstone says: "Nuisance, *nocumentum*, or annoyance, signifies anything which worketh hurt, inconvenience, or damage. And nuisances are of two kinds—*public* or *common* nuisances which affect the public and are an annoyance to all the King's subjects, for which reason we must refer them to the class of public wrongs or crimes and misdemeanors; and *private* nuisances, which are the objects of our present consideration and may be defined as anything done to the hurt or annoyance of the lands, tenements, or hereditaments of another."

Lord Mansfield, C.J., says: "To constitute a nuisance it is enough that the matter complained of renders the enjoyment of life and property uncomfortable." Seeing that there

is no definition of a nuisance by law, many magistrates will not order the nuisance to be abated unless it is both a nuisance and injurious to health. The sanitary inspector will therefore have to be guided in his action by the opinion of the medical officer of health and the view of the town clerk or other legal adviser on the whole question.

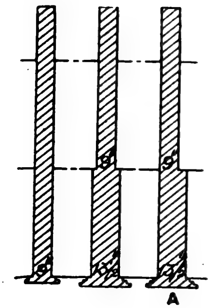
The sanitary inspector will often be asked to advise a cure for damp walls, as, unfortunately, there are damp walls in existence in spite of M.B.L. and other sanitary regulations. The first step to a cure is to find out the cause, and, having done this, to apply a suitable remedy; and these remedies should generally be on the following lines: If the damp springs from the surrounding earth, a dry area (see Figs. 44, 45, and 46) or external cavity should be constructed, or the wall should be asphalted, and an open-joint drain laid; if from the absence of a damp-course, a course of bricks should be cut out and a damp-proof course inserted. If the mortar absorbs the moisture and transmits it to the inside, the outside should be pointed with cement or other impervious mortar. If the bricks are at fault, the whole outer face of the wall should be painted or tarred, or covered with slates. Or a 4½-in. wall may be built up on the inside of the room, leaving a ½-in. cavity, which is then to be filled with asphalt. On no account should the inner face of the wall be covered with sheet lead or other impervious lining. It is an absolute necessity that the walls should absorb the moisture generated in the room; otherwise, the moisture will condense on the surface of the wall, run down in unsightly streams, and form a sticky slime on it.

CHAPTER V.

STABILITY OF WALLS.

THERE is great risk of permanent injury to health in a house where the walls are collapsing from weakness, and bye-laws have been framed dealing with the stability of walls. M.B.L. No. 21 indicates how measurements shall be taken :—

M.B.L. No. 21 : " For the purposes of the bye-laws with



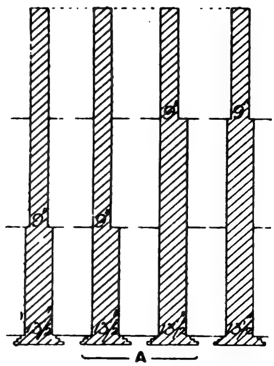


Fig. 47. Fig. 48. Fig. 49. Fig. 50. Fig. 51. Fig. 52. Fig. 53.

Fig. 47.—Internal wall not exceeding 25 ft. high and 30 ft. in length. Fig. 48.—Internal wall not exceeding 25 ft. high and exceeding 30 ft. in length. Fig. 49.—External wall not exceeding 25 ft. high and exceeding 30 ft. in length. Fig. 50.—Internal wall 25 ft. to 30 ft. high not exceeding 35 ft. in length. Fig. 51.—External wall 25 ft. to 30 ft. high not exceeding 35 ft. in length. Fig. 52.—External wall 25 ft. to 30 ft. high and exceeding 35 ft. in length. Fig. 53.—Internal wall 25 ft. to 30 ft. high and exceeding 35 ft. in length.

respect to the structure of walls of new buildings, the measurement of height of storeys and of height and length of walls shall be determined by the following rules :—(i) The height of a storey shall be measured in the case of the lowest storey of a building from the base of the wall, and in the case of any other storey from the level of the upper surface of the floor of the storey up to the level of the upper surface of

the floor of the storey next above it; or if there be no such storey, then up to the highest part of the containing walls. (ii) The height of a wall shall be measured from the base to the highest part of the wall, or in the case of a wall comprising a gable, to half the height of the gable: provided that in the case of a party wall comprising a gable the measurement shall be from the base of the wall to the level of the

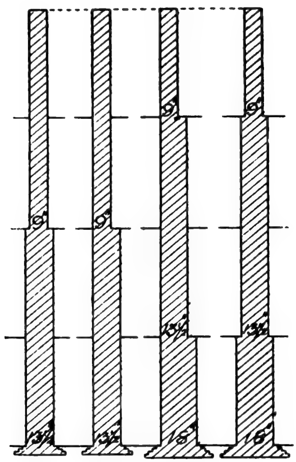


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Fig. 54. Fig. 55. Fig. 56. Fig. 57.

Fig. 54.—Internal wall 30 ft. to 40 ft. high not exceeding 35 ft. in length. Fig. 55.—External wall 30 ft. to 40 ft. high not exceeding 35 ft. in length. Fig. 56.—External wall 30 ft. to 40 ft. high and exceeding 35 ft. in length. Fig. 57.—Internal wall 30 ft. to 40 ft. high and exceeding 35 ft. in length.

base of the gable. (iii) Walls shall be deemed to be divided into distinct lengths by return walls. The length of a wall shall be measured from the centre of one return wall to the centre of another, provided that the return walls are external walls, party walls, or cross walls, of the thickness prescribed by the bye-laws, and are bonded into the walls so deemed to be divided. A wall shall not, for the purpose of this rule, be deemed a cross wall unless it is carried up to the top of the wall so deemed to be divided (or in the case of

a gable wall to the level of the base of the gable), and unless in each storey the aggregate extent of the vertical faces or elevations of all the recesses and that of all the openings therein, taken together, shall not exceed one-half of the

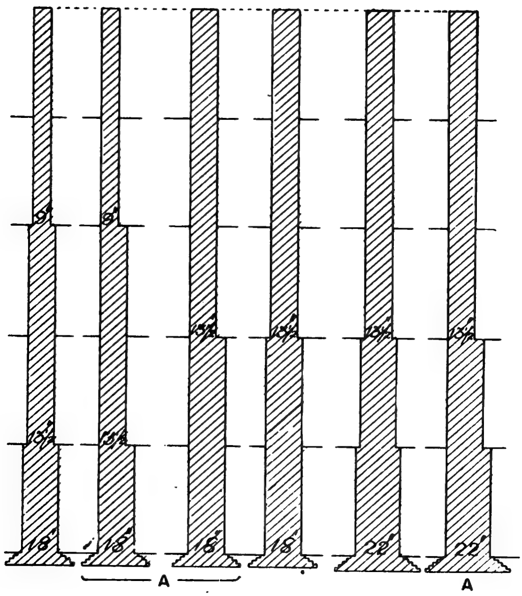


Fig. 58. Fig. 59. Fig. 60. Fig. 61. Fig. 62. Fig. 63.

Fig. 58.—Internal wall 40 ft. to 50 ft. high not exceeding 30 ft. in length. Fig. 59.—External wall 40 ft. to 50 ft. high not exceeding 30 ft. in length. Fig. 60.—External wall 40 ft. to 50 ft. high not exceeding 45 ft. in length. Fig. 61.—Internal wall 40 ft. to 50 ft. high not exceeding 45 ft. in length. Fig. 62.—Internal wall 40 ft. to 50 ft. high and exceeding 45 ft. in length. Fig. 63.—External wall 40 ft. to 50 ft. high and exceeding 45 ft. in length.

whole extent of the vertical face or elevation of the wall in such storey."

M.B.L. No. 22 then proceeds to specify particularly the various thicknesses of wall for various heights and lengths. In the following illustrations the horizontal measurements have been reproduced to twice the scale of the vertical measurements, and in each case the letter A indicates an external wall.

M.B.L. No. 22: "Every person who shall erect a new domestic building shall construct every external wall and every party wall of such building in accordance with the following rules, and in every case the thickness prescribed

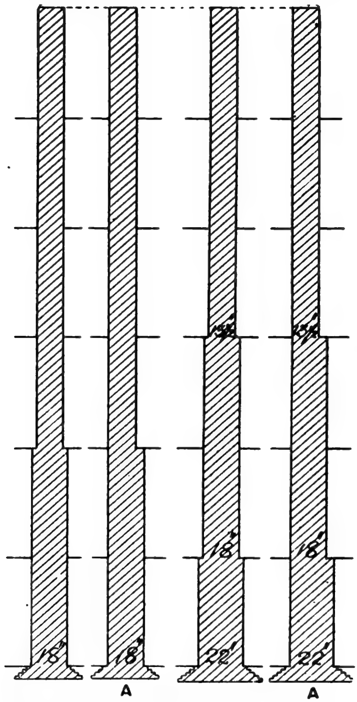


Fig. 64. Fig. 65. Fig. 66. Fig. 67.

Fig. 64.—Internal wall 50 ft. to 60 ft. high not exceeding 45 ft. in length. Fig. 65.—External wall 50 ft. to 60 ft. high not exceeding 45 ft. in length. Fig. 66.—Internal wall 50 ft. to 60 ft. high and exceeding 45 ft. in length. Fig. 67.—External wall 50 ft. to 60 ft. high and exceeding 45 ft. in length.

shall be the minimum thickness of which any such wall may be constructed, and the several rules shall apply only to walls built of good bricks not less than 9 in. long, or of suitable stone or other blocks of hard and incombustible

substance, the beds or courses being horizontal. (*a*) Where the wall does not exceed 25 ft. in height, its thickness shall

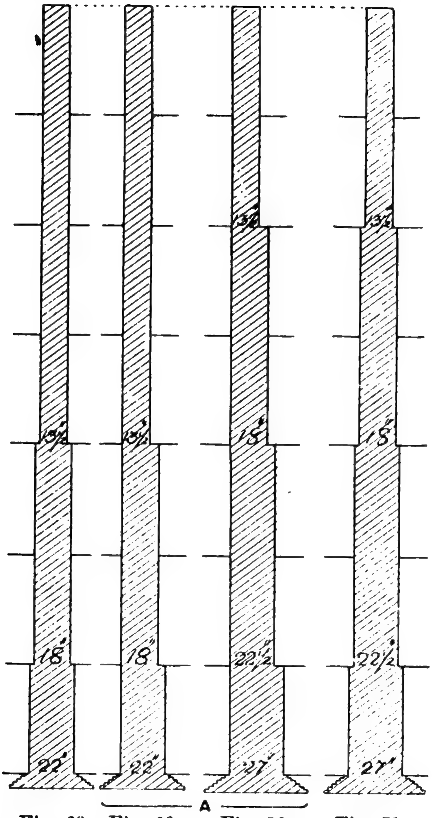


Fig. 68. Fig. 69. Fig. 70. Fig. 71.

Fig. 68.—Internal wall 60 ft. to 70 ft. high not exceeding 45 ft. in length. Fig. 69.—External wall 60 ft. to 70 ft. high not exceeding 45 ft. in length. Fig. 70.—External wall 60 ft. to 70 ft. high and exceeding 45 ft. in length. Fig. 71.—Internal wall 60 ft. to 70 ft. high and exceeding 45 ft. in length.

be as follows :—If the wall does not exceed 30 ft. in length, it shall be 9 in. thick for its whole height (Fig. 47). If the

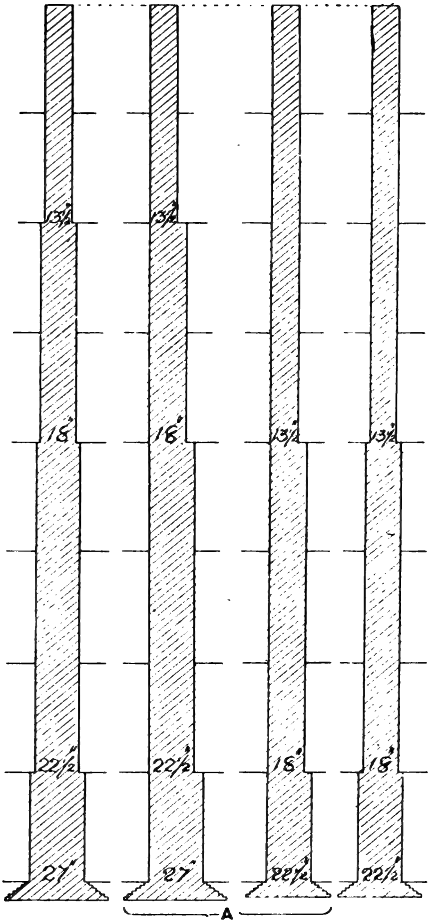


Fig. 72. Fig. 73. Fig. 74. Fig. 75.

Fig. 72.—Internal wall 70 ft. to 80 ft. high and exceeding 45 ft. in length. Fig. 73.—External wall 70 ft. to 80 ft. high and exceeding 45 ft. in length. Fig. 74.—External wall 70 ft. to 80 ft. high not exceeding 45 ft. in length. Fig. 75.—Internal wall 70 ft. to 80 ft. high not exceeding 45 ft. in length.

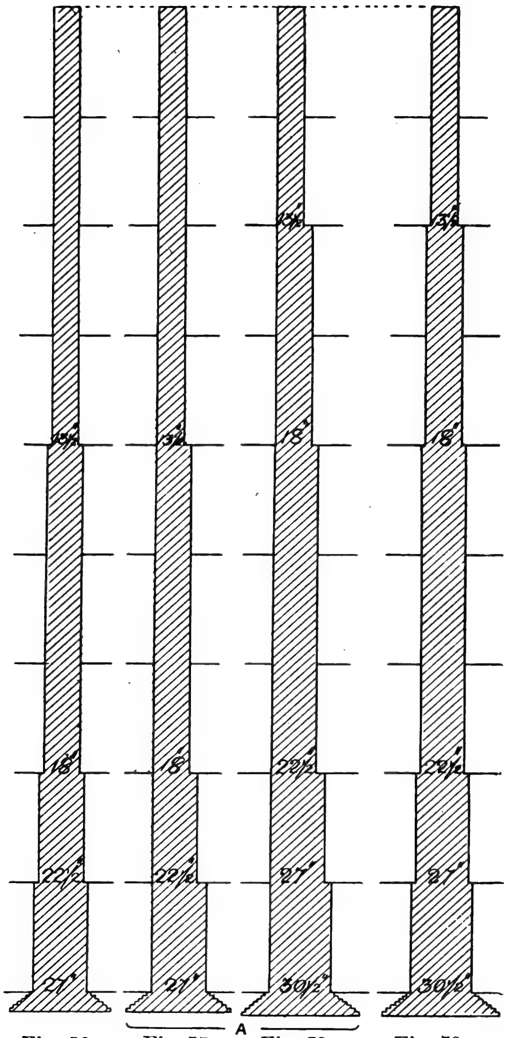


Fig. 76. Fig. 77. Fig. 78. Fig. 79.

Fig. 76.—Internal wall 80 ft. to 90 ft. high not exceeding 45 ft. in length. Fig. 77.—External wall 80 ft. to 90 ft. high not exceeding 45 ft. in length. Fig. 78.—External wall 80 ft. to 90 ft. high and exceeding 45 ft. in length. Fig. 79.—Internal wall 80 ft. to 90 ft. high and exceeding 45 ft. in length.

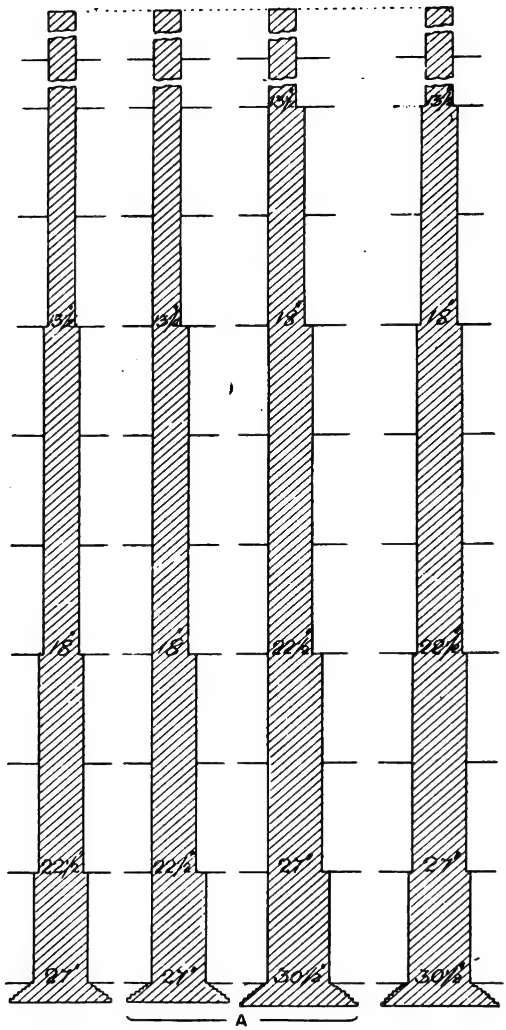


Fig. 80. Fig. 81. Fig. 82. Fig. 83.

Fig. 80.—Internal wall 90 ft. to 100 ft. high not exceeding 45 ft. in length. Fig. 81.—External wall 90 ft. to 100 ft. high not exceeding 45 ft. in length. Fig. 82.—External wall 90 ft. to 100 ft. high and exceeding 45 ft. in length. Fig. 83.—Internal wall 90 ft. to 100 ft. high and exceeding 45 ft. in length.

wall exceeds 30 ft. in length, it shall be 13½ in. thick from the base for the height of the lowest storey, and 9 in. thick for the rest of its height (Fig. 48). (*b*) Where the wall exceeds 25 ft. but does not exceed 30 ft. in height, its thickness shall be as follows :—If the wall does not exceed 35 ft. in length, it shall be 13½ in. thick from the base for the height of one storey, and 9 in. thick for the rest of its height (Fig. 50). If the wall exceeds 35 ft. in length, it shall be 13½ in. thick from the base for the height of two storeys, and 9 in. thick for the rest of its height (Fig. 53). (*c*) Where the wall exceeds 30 ft. but does not exceed 40 ft. in height, its thickness shall be as follows :—If the wall does not exceed 35 ft. in length, it shall be 13½ in. thick from the base for the height of two storeys, and 9 in. thick for the rest of its height (Fig. 54); if the wall exceeds 35 ft. in length, it shall be 18 in. thick from the base for the height of one storey, then 13½ in. thick for the height of two storeys, and 9 in. thick for the rest of its height (Fig. 57). (*d*) Where the wall exceeds 40 ft. but does not exceed 50 ft. in height, its thickness shall be as follows :—If the wall does not exceed 30 ft. in length, it shall be 18 in. thick from the base for the height of one storey, then 13½ in. thick for the height of two storeys, and then 9 in. for the rest of its height (Fig. 58); if the wall exceeds 30 ft. but does not exceed 45 ft. in length, it shall be 18 in. thick from the base for the height of two storeys, and 13½ in. thick for the rest of its height (Fig. 61); if the wall exceeds 45 ft. in length, it shall be 22 in. thick from the base for the height of one storey, then 18 in. thick for the height of the next storey, and then 13½ in. thick for the rest of its height (Fig. 62). (*e*) Where the wall exceeds 50 ft. but does not exceed 60 ft. in height, its thickness shall be as follows :—If the wall does not exceed 45 ft. in length, it shall be 18 in. thick from the base for the height of two storeys and 13½ in. thick for the rest of its height (Fig. 64); if the wall exceeds 45 ft. in length, it shall be 22 in. thick from the base for the height of one storey, then 18 in. thick for the height of the next two storeys, and then 13½ in. thick for the rest of its height (Fig. 66). (*f*) Where the wall exceeds 60 feet but does not exceed 70 ft. in height, its thickness shall be as follows :—If the wall does not exceed 45 ft. in length, it shall be 22 in. thick from the base for the height of one storey, then 18 in.

thick for the height of the next two storeys, and then 13½ in. thick for the rest of its height (Fig. 68); if the wall exceeds 45 ft. in length, it shall be increased in thickness in each of the storeys below the uppermost two storeys by 4½ in. (subject to the provision hereinafter contained respecting distribution in piers). (*g*) Where the wall exceeds 70 ft. but does not exceed 80 ft. in height, its thickness shall be as follows:—If the wall does not exceed 45 ft. in length, it shall be 22 in. thick from the base for the height of one storey, then 18 in. thick for the height of the next three storeys, and then 13½ in. thick for the rest of its height (Fig. 75); if the wall exceeds 45 ft. in length, it shall be increased in thickness in each of the storeys below the uppermost two storeys by 4½ in. (subject to the provision hereinafter contained respecting distribution in piers). (*h*) Where the wall exceeds 80 ft. but does not exceed 90 ft. in height, its thickness shall be as follows:—If the wall does not exceed 45 ft. in length, it shall be 26 in. thick from the base for the height of one storey, then 22 in. thick for the height of the next storey, then 18 in. thick for the height of the next three storeys, and then 13½ in. thick for the rest of its height (Fig. 76); if the wall exceeds 45 ft. in length, it shall be increased in thickness in each of the storeys below the uppermost two storeys by 4½ in. (subject to the provision hereinafter contained respecting distribution in piers). (*i*) Where the wall exceeds 90 ft. but does not exceed 100 ft. in height, its thickness shall be as follows:—If the wall does not exceed 45 ft. in length, it shall be 26 in. thick from the base for the height of one storey, then 22 in. thick for the height of the next two storeys, then 18 in. thick for the height of the next three storeys, and then 13½ in. thick for the rest of its height (Fig. 80); if the wall exceeds 45 ft. in length, it shall be increased in thickness in each of the storeys below the uppermost two storeys by 4½ in. (subject to the provision hereinafter contained respecting distribution of piers).

"Provided that notwithstanding anything contained in the foregoing rules (*a*) to (*i*) inclusive—(i) Every external and party wall of any storey which measured from the level of the floor of that storey to the level of the floor of the storey next above it, if any, exceeds 11 ft. in height shall be not less than 13½ in. in thickness; and (ii) if any storey exceeds

in height sixteen times the thickness hereinbefore prescribed for its walls, the thickness of each external and party wall throughout that storey shall be increased to one-sixteenth part of the height of the storey, and the thickness of each external wall and of each party wall below that storey shall be proportionately increased (subject to the provision hereinafter contained respecting distribution in piers).

"Provided further that where in accordance with the requirements of this bye-law an increase of thickness is required in the case of a wall exceeding 60 ft. in height and 45 ft. in length, or in the case of a storey exceeding in height sixteen times the thickness prescribed for its walls or in the case of a wall below that storey, the increased thickness may be confined to piers properly distributed, of which the collected widths amount to one-fourth part of the length of the wall. The width of the piers may nevertheless be reduced if the projection is proportionately increased, the horizontal sectional area not being diminished; but the projection of any such pier shall in no case exceed one-third of its width."

M.B.L. No. 23 need not be reproduced, as it merely consists of similar regulations for the walls of public buildings and buildings of the warehouse class. The M.B.L. then proceed to define the thickness of cross walls, which are generally to be two-thirds the thickness of an external wall of the same height and length, but in no case less than 9 in.

M.B.L. No. 24: "Every person who shall erect a new building shall construct, in accordance with the following rules, every cross wall which, in pursuance of the bye-law in that behalf, may, as a return wall, be deemed a means of determining the length of any external wall or party wall of such building; and in every case the thickness prescribed shall be the minimum thickness of which any such wall may be constructed; and the several rules shall apply only to walls built of good bricks not less than 9 in. long, or of suitable stone or other blocks of hard and incombustible substance, the beds or courses being horizontal. The thickness of every such cross wall shall be at least two-thirds of the thickness prescribed by the bye-law in that behalf for an external wall or party wall of the same height and length, and belonging to the same class of building as that to which such cross wall belongs, but shall in no case be less than

9 in.; but if such cross wall supports a superincumbent external wall the whole of such cross wall shall be of the thickness prescribed by the bye-law in that behalf for an external wall of a party wall of the same height and length and belonging to the same class of building as that to which such cross wall belongs."

M.B.L. No. 25 provides for the thickness of walls when constructed of other materials than bricks:—"Every person who shall erect a new building and shall construct any external wall, party wall, or cross wall of such building of any material other than good bricks or suitable stone or other blocks of hard and incombustible substance, the beds or courses being horizontal, shall comply with the following rules with respect to the thickness of such wall:—(*a*) Where a wall is built of stone or of clunches of bricks, or other burnt or vitrified material, the beds or courses not being horizontal, or of flintwork, the thickness of such wall shall be one-third greater than that prescribed by the bye-law in that behalf for a wall built of bricks, but in other respects of the same description, height, and length, and belonging to the same class of building; (*b*) A wall built of brickwork and flintwork, in which the proportion of brickwork is equal to at least one-fifth of the entire content of the wall and is properly distributed in piers and horizontal courses, or of half timber work, or of other suitable material not specifically mentioned in this bye-law, shall be deemed to be of sufficient thickness if constructed of the thickness prescribed by the bye-law in that behalf for a wall built of bricks, but in other respects of the same description, height, and length, and belonging to the same class of building. Provided always that this bye-law shall not be deemed to apply to any part of an external wall of a new building which may, in accordance with the provisions of the bye-law in that behalf, be constructed of timber-framing covered with tiles."

The next M.B.L. provides for the maximum amount of openings that may be put in an external wall:—

M.B.L. No. 26: "Every person who shall erect a new building and shall leave in any storey or storeys of such building an extent of opening in any external wall which shall be greater than one-half of the whole extent of the vertical face or elevation of the wall or walls of the storey

or storeys in which the opening is left shall construct—(*a*) Sufficient piers of brickwork or other sufficient supports of incombustible material so disposed as to carry the superstructure ; and (*b*) A sufficient pier or piers or other sufficient supports of that description, at or within 3 ft. of the corner or angle of the building."

M.B.L. No. 27 relates to the prevention of the spread of fire from a burning building to an adjacent building :— "Every person who shall erect a new public building, a new building of the warehouse class, or a new domestic building which may be intended to be used wholly or partly as a shop or as a place of habitual employment for any person in any manufacture, trade, or business, or which may be intended to be used exclusively as a dwelling-house and may exceed 30 ft. in height, shall cause such part of any external wall of such building as is within a distance of 15 ft. from any other building to be carried up so as to form a parapet 1 ft. at least above the highest part of any roof or gutter which adjoins such part of such external wall, and he shall cause the thickness of the parapet so carried up to be at least 9 in. throughout."

The succeeding M.B.L. are also directed to the prevention of the spread of fire, so far as regards party walls :—

M.B.L. No. 28A : "(1) Every person who shall erect a new public building, a new building of the warehouse class, or a new domestic building which may be intended to be used wholly or partly as a shop or as a place of habitual employment for any person in any manufacture, trade, or business, or which may be intended to be used exclusively as a dwelling-house and may exceed 30 ft. in height, shall cause every party wall of such building to be carried up 9 in. at the least in thickness :—(*a*) Above the roof, flat, or gutter of the highest building adjoining thereto to such height as will give in the case of a public building or of a building of the warehouse class, a distance of at least 3 ft., and, in the case of any such domestic building as is hereinbefore described, a distance of at least 15 in. measured at right angles to the slope of the roof, or above the highest part of any flat or gutter, as the case may be : (*b*) Above any turret, dormer, lantern-light, or other erection of combustible materials fixed on the roof or flat of any building

within 4 ft. from the party wall, and so as to extend at least 12 in. higher and wider on each side than such erection; (c) To a height of 12 in. at the least above such part of any roof as is opposite to and within 4 ft. from the party wall.

"In every case where the eaves of the roof project beyond the face of the building, he shall cause every party wall of such building to be properly corbelled out, in brickwork, or stonework, to the full extent of such projection, and to be carried up above the projecting eaves, 9 in. at the least in thickness, to such height as will give, in the case of a public building or of a building of the warehouse class, a distance of at least 3 ft., and, in the case of any such domestic building as is hereinbefore described, a distance of at least 15 in. measured at right angles to the slope of the roof.

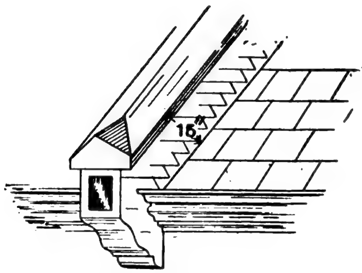


Fig. 84.—Party Wall Corbelled out and Carried above Eaves.

"(2) Every person who shall erect a new domestic building which may be intended to be used exclusively as a dwelling-house and may not exceed 30 ft. in height, or which may be intended to be used as an office building or other out-building appurtenant to a dwelling-house, whether attached thereto or not, shall cause every party wall of such building to be carried up at least as high as the underside of the slates or other covering of the roof of such building; and if such party wall be carried up only to the underside of such slates or other covering, he shall cause such slates or other covering to be properly and solidly bedded in mortar or cement on the top of the wall. He shall also cause the roof to be so constructed that no lath, timber, or woodwork of any description shall extend upon or across any part of such wall.

"(3) For the purposes of this bye-law, the height of a building shall be measured upwards from the top of the footings of the walls thereof to the level of half the vertical height of the roof, or to the top of the parapet, whichever may be the higher."

This apparently complicated regulation will be better understood by reference to Fig. 84, which illustrates the first two paragraphs. Paragraph (2) needs no illustration. In a Note to this bye-law, the annotator points out :—

"If § 109 of the Towns Improvement Clauses Act, 1847 (10 & 11 Vict. c. 34), is in force by reason of its incorporation with a local Act, this clause must be omitted. If in any case, however, § 109 of the Act of 1847 is not in force, and the model clause is regarded as too stringent, the following clause must be included so as to secure that all party walls are carried up to the underside of the roofs, as it should not be permissible to erect houses in rows so that there may be uninterrupted intercommunication under a continuous roof, as such an arrangement involves great danger from the spread of fire and consequent risk to life, as well as being very objectionable from a sanitary point of view in facilitating the spread of certain infectious diseases."

The following is the alternative bye-law referred to in the Note :—

M.B.L. No. 28B : "Every person who shall erect a new building shall cause every party wall of such building to be carried up at least as high as the underside of the slates or other covering of the roof of such building ; and if such party wall be carried up only to the underside of such slates or other covering, he shall cause such slates or other covering to be properly and solidly bedded in mortar or cement on the top of the wall. He shall also cause the roof to be so constructed that no lath, timber, or woodwork of any description shall extend upon or across any part of such wall."

The succeeding M.B.L. explain themselves :—

M.B.L. No. 29 : "Every person who shall erect a new building shall cause every wall of such building, when carried up above any roof, flat, or gutter, so as to form a parapet, to be properly coped or otherwise protected, in order to prevent water from running down the sides of such parapet or soaking into any wall."

M.B.L. No. 30: "A person who shall erect a new building shall not construct any party wall of such building so that any opening shall be made or left in such wall."

M.B.L. No. 31: "A person who shall erect a new building shall not make any recess in any external wall or party wall of such building:—(*a*) Unless the back of such recess be at the least 9 in. thick; (*b*) Unless a sufficient arch be turned or a lintel of incombustible material placed in every storey over every such recess; (*c*) Unless in each storey the aggregate extent of recesses having backs of less thickness than the thickness prescribed by any bye-law in that behalf for the wall in which such recesses are made do not exceed one-half of the extent of the vertical superfices of such wall; (*d*) Unless the side of any such recess nearest to the inner face of any return external wall is distant at the least 13½ in. therefrom."

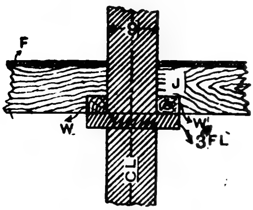


Fig. 85.

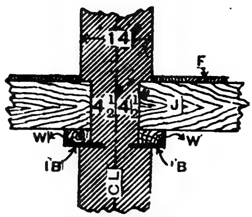


Fig. 86.

Figs. 85 and 86.—Showing Construction of Party Walls, as laid down in M.B.L. Nos. 33 and 34.

M.B.L. No. 32: "A person who shall erect a new building shall not make in any wall of such building any chase which shall be wider than 14 in. or more than 4½ in. deep from the face of such wall, or shall leave less than 9 in. in thickness at the back or opposite side thereof, or which shall be within 13½ in. from any other chase, or within 7 ft. from any other chase on the same side of such wall, or within 13½ in. from any return wall."

M.B.L. No. 33: "A person who shall erect a new building shall not place in any party wall of such building any bond timber or any wood plate."

M.B.L. No. 34 : "A person who shall erect a new building shall not place the end of any bressummer, beam, or joist in any party wall of such building, unless the end of such bressummer, beam, or joist be at least 4½ in. distant from the centre line of such party wall. Provided always that in the case of a party wall not exceeding 9 in. in thickness such person may place the end of any such bressummer, beam, or joist so that it may extend to the centre line of such party wall if the end of such bressummer, beam, or joist be encased in not less than 4½ in. of solid brickwork or other solid and incombustible material."

In some cases the proviso is added that this bye-law shall not apply to any bressummer, beam, or joist constructed wholly of metal.

M.B.L. No. 35 : "Every person who shall erect a new building shall cause every bressummer to be borne by a sufficient template of stone, iron, terra-cotta, or vitrified stoneware of the full breadth of the bressummer, and to have a bearing in the direction of its length of 4 in. at least at each end. He shall also, if necessary, cause such bressummer to have such storey posts, iron columns, stanchions, or piers of brick or stone on a solid foundation under the same as may be sufficient to carry the superstructure."

Figs. 85 and 86 indicate methods of construction which may be adopted in order to comply with the restrictions contained in Bye-laws Nos. 33 and 34. C L signifies centre line, F floor, FL flag, J joist, W wall-plate, I B iron bracket.

The following M.B.L. have reference to chimneys, and need no explanatory remarks :—

M.B.L. No. 36 : "Every person who shall erect a new building shall, except in such case as is hereinafter provided, cause every chimney of such building to be built on solid foundations and with footings similar to the footings of the wall against which such chimney is built, and to be properly bonded into such wall : Provided, nevertheless, that such person may cause any chimney of such building to be built on a metal girder, or on sufficient corbels of brick, stone, or other hard and incombustible materials, if the work so corbelled out does not project from the wall more than the thickness of the wall measured immediately below the corbel."

M.B.L. No. 37: "Every person who shall erect a new building shall cause the inside of every flue of such building to be properly rendered or pargeted as such flue is carried up, unless the whole flue shall be lined with fireproof piping of stoneware at least 1 in. thick, and unless the spandril angles shall be filled in solid with brickwork or other incombustible materials. Such person shall also cause the back or outside of such flue, which shall not be constructed so as to form part of the outer face of an external wall, to be properly rendered in every case where the brickwork of which such back or outside may be constructed is less than 9 in. thick."

The M.B.L. contain no provisions for regulating the construction of chimney shafts; but the following clause, to be modified to suit local requirements, is recommended for use in districts where control is desired:—

M.B.L. No. 37A: "Every person who, in erecting a new building, shall construct any chimney shaft for the furnace of a steam boiler, brewery, distillery, or manufactory, shall comply with the following rules:—(*a*) He shall cause such chimney-shaft to be carried up throughout in brickwork, composed of the best hard, well-burnt bricks, laid in lime mortar of the best quality, properly bonded and solidly put together upon a solid and level bed of good concrete of sufficient size and thickness, extending beyond the lowest course of footings at least 18 in. on all sides, and having a minimum thickness of 18 in. (*b*) He shall cause the base of the shaft to be constructed of solid brickwork to the level of the top of the footings, and the footings shall spread equally all round the exterior of the base by regular offsets, at least 3 in. high, and 2¼ in. wide, to a projection on all sides equal at least to the thickness of the brickwork enclosing the shaft at the level of the top of the footings. (*c*) He shall cause the external diameter of a shaft measured immediately above the footings to be as follows:—Where the shaft is square on plan, the external diameter of the shaft shall be at least one-tenth of the total height of the shaft; where the shaft is polygonal on plan, the external diameter of the shaft shall be at least one-eleventh of the total height of the shaft; where the shaft is circular on plan, the external diameter of the shaft shall be at least one-

twelfth of the total height of the shaft. In the case of a shaft which is square or polygonal on plan, the external diameter shall, for the purposes of this bye-law, be measured from the centre of one face or side to the centre of the opposite face or side. (*d*) He shall cause the brickwork enclosing the shaft to be built with a batter (or inclination inwards) of 2½ in. at least in every 10 ft. of height. (*e*) He shall cause the brickwork enclosing the shaft to be at least 9 in. in thickness at the top of the shaft and for a distance not exceeding 20 ft. below the top, and to be increased in thickness at least 4½ in. for every additional 20 ft. measured downwards. He shall not cause any portion of the work required by this paragraph to be constructed of fire-bricks. (*f*) He shall cause the shaft to be provided, for at least one-sixth of its height, with an independent lining of fire-bricks, separated from the brickwork enclosing the shaft by a cavity at least 1 in. in width; and he shall cause such cavity to be covered at the top with corbelled brickwork. (*g*) The total height of the shaft shall, for the purposes of this bye-law, be its height measured from the top of the footings."

M.B.L. No. 38: "Every person who shall erect a new building shall cause every flue in such building which may be intended for use in connection with any furnace, cockle, steam-boiler, or close-fire, constructed for any purpose of trade, business, or manufacture, or which may be intended for use in connection with any cooking range or cooking apparatus of such building when occupied as an hotel, tavern, or eating-house, to be surrounded with brickwork or other solid and incombustible material at least 9 in. thick for a distance of 10 ft. at the least in height from the floor on which such furnace, cockle, steam-boiler, close-fire, cooking range, or cooking apparatus may be constructed or placed."

M.B.L. No. 39: "Every person who shall erect a new building shall cause a sufficient arch of brick or stone, or a sufficient stone lintel, or a sufficient bar of wrought-iron to be built over the opening of every chimney of such building to support the breast of such chimney; and if the breast projects more than 4½ in. from the face of the wall, and the jamb on either side is of less width than 13½ in., he shall cause the abutments to be tied in by a bar or bars of wrought-iron of sufficient strength, 18 in. longer than the opening,

turned up and down at the ends, and built into the jambs on each side."

M.B.L. No. 40: "Every person who shall erect a new building shall cause the jambs of every chimney of such building to be at least 9 in. wide on each side of the opening of such chimney."

M.B.L. No. 41: "Every person who shall erect a new building shall cause the breast of every chimney of such building, and the brickwork or stonework surrounding every smoke flue and every copper flue of such building, to be at least 4½ in. in thickness."

M.B.L. No. 42: "Every person who shall erect a new building shall cause the back of any chimney opening in a party wall and [at] the back of the flue connected therewith in any room which may be constructed for occupation as a kitchen to be at least 9 in. thick to the height of at least 9 ft. above the hearth. Such person shall cause the back of every other chimney opening in such building, from the hearth up to the height of 12 in. above such opening, to be at least 4½ in. thick in the case of an external wall, and 9 in. thick in the case of any other wall."

The bracketed word "at" in the above bye-law has been retained in error, and should be omitted.

M.B.L. No. 43: "Every person who shall erect a new building shall cause the upper side of every flue of such building, when the course of such flue makes with the horizon an angle of less than 45°, to be at least 9 in. in thickness."

The following clause relating to the support of chimneys on arches formed part of the original model, but has been omitted. It may, however, be added in any case where it is considered necessary:—

"Every person who shall erect a new building shall construct every arch upon which any flue may be carried so that such arch shall be effectually supported by means of a bar or bars of wrought-iron of adequate strength. He shall cause every such bar, to the extent of 4½ in., to be securely built or pinned into the wall at each end thereof. He shall provide, for every 9 in. of the width of the soffit of such arch, one at the least of such bars as a means of support for such arch."

M.B.L. No. 44: "Every person who shall erect a new

building shall cause every chimney shaft or smoke flue of such building to be carried up in brickwork or stonework all round at least 4½ in. thick to a height of not less than 3 ft. above the roof, flat, or gutter adjoining thereto, measured at the highest point in the line of junction with such roof, flat, or gutter."

M.B.L. No. 45: "A person who shall erect a new building shall not cause the brickwork or stonework of any chimney shaft of such building other than a chimney shaft of the furnace of any steam-engine, brewery, distillery, or manufactory, to be built higher above the roof, flat, or gutter adjoining such chimney shaft, measured from the highest point in the line of junction with such roof, flat, or gutter, than a height equal to six times the least width of such chimney shaft at the level of such highest point, unless such chimney shaft shall be built with and bonded to another chimney shaft not in the same line with such first-mentioned chimney shaft, or shall be otherwise made secure."

M.B.L. No. 46: "A person who shall erect a new building shall not place any iron holdfast or other metal fastening nearer than 2 in. to the inside of any flue or chimney-opening in such building."

M.B.L. No. 47: "A person who shall erect a new building shall not place any timber or woodwork—(*a*) In any wall or chimney breast of such building nearer than 9 in. to the inside of any flue or chimney-opening; (*b*) Under any chimney-opening of such building within 10 in. from the upper surface of the hearth thereof. A person who shall erect a new building shall not drive any wooden plug into any wall or chimney breast of such building nearer than 6 in. to the inside of any flue or chimney-opening."

M.B.L. No. 48: "Every person who shall erect a new building shall cause the face of the brickwork or stonework about any flue or chimney-opening of such building, where such face is at a distance of less than 2 in. from any timber or woodwork, and where the substance of such brickwork or stonework is less than 9 in. thick, to be properly rendered."

M.B.L. No. 49: "A person who shall erect a new building shall not construct any chimney or flue of such building so as to make or leave in such chimney or flue any opening for the insertion of any ventilating valve, or for any other

purpose, unless such opening be at least 9 in. distant from any timber or other combustible substance."

M.B.L. No. 50 : "A person who shall erect a new building shall not fix in such building any pipe for the purpose of conveying smoke or other products of combustion, unless such pipe be so fixed at the distance of 9 in. at the least from any combustible substance."

It may be pointed out, with regard to the size of chimney flues, that this part of the subject is dealt with in the Chimney Sweepers and Chimneys Act, 1840 (3 and 4 Vict. cap. 85), where § 6 enacts that " . . . every chimney or flue hereafter to be built or rebuilt in any wall, or of greater length than 4 ft. out of the wall, not being a circular chimney or flue 12 in. in diameter, shall be in every section of the same not less than 14 in. by 9 in. . . ." No Local Authority therefore may adopt any lesser size.

CHAPTER VI.

ROOFS.

M.B.L. No. 51 is designed to prevent the use of thatch, tarred felt, and other combustible materials as roof-covering, and reads as follows :—

M.B.L. No. 51 : " Every person who shall erect a new building shall cause the flat and roof of such building, and every turret, dormer, lantern-light, skylight, or other erection placed on the flat or roof of such building, to be externally covered with slates, tiles, metal, or other incombustible materials, except as regards any door, door frame, window or window frame of any such turret, dormer, lantern-light, skylight, or other erection."

The following notes on roof-covering materials are from a lecture on this subject by Mr. Keith D. Young, M.San.I., and so completely cover the ground that they may be fittingly introduced here :—

" The materials in ordinary use for roofing are tiles, slates, lead, zinc, and thatch. *Tiles* are made in several ways ; the plain tile is rectangular in form, with two holes at its upper edge, through which the oak or iron pins are driven, by which the tile is hung to the lath or batten. The pantile is a tile bent to a double curve and furnished with a small stub or projection, by which it is hooked on to the lath ; variations of this are the double-roll tile and the corrugated tile. Taylor's patent tiles are narrower at one end than at the other, and have the edges at each side turned up ; these are laid alternately as capping and channel tiles. The Venetian or Italian tiles have a flat surface alternating with a roll. Of all these the plain tile is the best. Tiles are, however, heavy, and they absorb a considerable percentage of water, and must therefore be laid at a steeper pitch than slates. They are difficult to repair, and, unless bedded on some yielding material, are, in exposed situations, liable to damage from high winds. For this reason it is

customary in many parts of the country to bed plain tiles in rushes, a practice involving the use of material liable to decay, which cannot be recommended. The desired object can be attained with equal efficiency by bedding the tiles in lime and hair. On the other hand, tiles are bad conductors of heat, and consequently are a warm covering in winter and a cool one in summer. Pantiles are more suitable for covering the roofs of out-houses and buildings not intended for habitation; they are, however, universally used in the county of Durham and in North Yorkshire.

"Slates are, as a rule, much thinner and lighter than tiles, and, being of a very compact crystalline nature, readily admit of the passage of heat and cold through them. The best and stoutest slates come from Cumberland; they are usually green in colour, and about ¼ in. thick. They are not sorted out into sizes, as are the Welsh slates, but all sizes are mixed. When laid on a roof the larger sizes are fixed at the eaves, and they gradually decrease in size until they reach the ridge. Welsh slates for the most part are blue or purple in colour, and are made in certain regular sizes, those in most ordinary use being 20 in. by 10 in., and known as 'countesses.' The best slates are those known as Bangor slates, and of these the greater proportion come from the famous Penrhyn quarries. The characteristics of a good slate are hardness, closeness of texture, and small capacity for absorption. It should give a clear ringing sound when struck, and its edges should cut clean when dressed. A good slate when immersed in water to half its length will show no sign of moisture above the water line. A good slate also should be free from veins or dark streaks, and should not contain lumps of iron pyrites, such as are frequently to be seen in an inferior kind of slate imported into this country from Germany.

"Slates, being much less absorbent than tiles, can be laid at a much lower pitch. Large slates may be laid at an angle of 22°, or a pitch of one-fifth the span; ordinary slates, as countesses, at an angle of 26½°, or one-quarter the span, and small slates at an angle of 45°, or one-half the span. The usual pitch adopted for countess slating in practice is ⅓ span, giving an angle of about 33°. The most important point in laying slating is to allow sufficient

lap. By lap is meant the distance by which each slate overlaps the next slate but one below it. 'Gauge' is the depth of margin of each slate exposed below the tail of the slate covering it.

"Slates should always be nailed near the centre in preference to near the head (except in the case of very small slates), as the leverage, when acted upon by the wind, is so much shorter, and the chance, therefore, of its being blown up so much less. Slating so laid is also easier to repair. The objection urged to this mode of nailing is that, when a slate slips, or gets blown off, the nail heads of the slate below are exposed, whereas, with head-nailing, each nail-head is covered by two slates, and they would therefore not be exposed by the removal of one slate. The lap should never be less than 3 in. with countess slates nailed near the centre; the gauge is equal to half the length of the slate, after deducting the lap. Thus, with a 3-in. lap, the gauge equals $8\frac{1}{2}$ in., or 20 in. — 3 in. $\div$ 2 = $8\frac{1}{2}$ in. The nail-holes are placed near the centre of the slate, but sufficiently near the head to clear the head of the slate below.

"The course of slates next the eaves is always double, and is tilted upwards, in order to give a perfectly even bed to all the slates, and to prevent the occurrence of any open space into which the wind could penetrate. In order to preserve a more equable temperature, a layer of boarding is sometimes nailed over the rafters, and on this sheet-felt is laid, to act as a non-conductor. It is a very good plan to fix the slates on battens over the felt, as by so doing an air space is obtained between the felt and the slates, which further increases the non-conducting property of the former.

"Lead and zinc are used chiefly for flat roofs. The great cost of lead prohibits its use in the smaller class of dwellings. It is heavy also, and involves the use of stronger framework to support it than is the case with zinc. The chief difficulty with lead is its liability to expansion and contraction with changes of temperature. For this reason no single piece of lead in a flat roof should be larger than 10 ft. by 3 ft.—a quarter of a sheet. The current at which it is laid should not be less than 1 in. in 10 ft., and the sheets should be laid lengthwise in the direction of the current. Where the sheets join one another lengthwise the lead is

dressed over semicircular wooden rolls, and at the ends a drop of 2 in. is formed, the upper and lower lead being dressed to overlap. It is important to see that the upper lead does not reach down to the lower lead where it overlaps, otherwise the water will be sucked under the upper lead by capillary attraction. Zinc is laid on very much the same principle as lead, but it is important to see that no solder is used in fixing it. Zinc is, compared with lead, very light, the stoutest zinc weighing 26 oz. to the superficial foot, while for flats and gutters the weight of lead should not be less than 7 lb. to the foot.

"Thatch as a roof-covering, notwithstanding its great advantage as a most efficient non-conductor of heat, is wholly unsuitable for dwelling-houses. It is in effect prohibited by the M.B.L. (No. 51) now under consideration, which requires that new buildings shall be covered with incombustible

Fig. 87.—Galvanised Corrugated Iron.

material. This bye-law is framed under § 157 of the P.H.A., 1875, which empowers Urban Authorities, and Rural Authorities too, when they have been invested by the L.G.B. with certain urban powers as allowed by the P.H.A., 1875, to make bye-laws with respect to the structure of walls, foundations, roofs, and chimneys of new buildings for securing stability and the prevention of fires and for the purposes of health, and is clearly directed at that part of the section which relates to the prevention of fire; but with regard to thatch, the question of health is of equal importance to that of fire. Thatch is an absorbent substance liable to decay, and has been proved to have the power of retaining the infective germs of specific disease for an almost unlimited period. For these reasons thatch must be unhesitatingly condemned as a roof-covering for dwelling-houses. Such a material as tarred felt also, though possibly not so absorbent as and less liable to decay than thatch, is of a most combustible nature, and as such would come under the pro-

hibition of the bye-law. Thatch has the further disadvantage that it does not permit of eaves-gathering, and consequently the rain-water from the roof cannot well be collected, and is allowed to drip on the ground so as to involve dampness in walls and foundations."

Sheet copper has been strongly advocated as a roof-covering, but there are very few who disregard expense when erecting a house, and consequently very few buildings are roofed with copper. It has, however, qualities that give it a high place among roof-coverings. It can be hammered and shaped to any form without injury; and, resisting oxidation and acids, it is found to last much longer than other metallic coverings. It is more durable than lead as a material for bearing traffic. Against lead, moreover, it possesses this important advantage, that it may be used at one-fifth the weight of lead; a building which would require 5 or 6 tons of lead to keep it weather-proof may be rendered equally secure, and for as long a time, with 1 ton of copper. In case of fire, also, while molten lead would pour down in streams, copper would remain uninjured. As against zinc, copper certainly is twice as costly to start with, but its durability may be taken to be three or four times that of zinc.

Galvanised corrugated iron is also apparently permissible under the bye-law, but its use should never be allowed where it can be prevented. It is formed of sheet iron bent to a wavy form (see Fig. 87), and is covered with a thin coating of zinc by dipping it in a bath of molten metal. It is supposed to be thus rendered non-corrodible. In practice, it is found to rust away very quickly; minute defects in the galvanising allow the acids of the smoke-laden atmosphere to be carried in by the rain, and even the most substantial work is rusted through in a very few years.

Concrete and asphalt roof-coverings are allowable, but great care is necessary to ensure their being constructed water-tight.

Duroline, a substance invented a few years ago, is composed of steel wire gauze thickly covered with a varnish or similar material; and being translucent, it was recommended as a substitute for glass in skylights. In the case of Payne *v.* Wright, however, it was held not to be "incom-

bustible material" (8 "*Times* Law Reports," 54), and consequently its use is prohibited wherever M.B.L. No. 51 has been adopted.

The M.B.L. contain no provisions with respect to the construction of roofs; but in an additional series prepared under the direction of Messrs. Knight and Co. (see Knight's Annotated Edition, pp. 194 *et seq.*), and approved by the L.G.B., the subject is fully dealt with as follows:—

"ROOFS.—Every person who shall erect a new building shall, as regards the construction of the roof of such building, comply with such of the following rules as may be applicable to such building, that is to say:—

"(i) *Common Rafters.*—He shall in the construction of the roof of a domestic building, public building, or building of the warehouse class, cause every common rafter to be of not less than the size and strength following:—(*a*) If the rafter does not exceed 6 ft. in clear bearing, it shall be 3 in. in depth and 2½ in. in thickness. (*b*) If the rafter exceeds 6 ft. and does not exceed 7½ ft. in clear bearing, it shall be 3 in. in depth and 3 in. in thickness. (*c*) If the rafter exceeds 7½ ft. and does not exceed 9 ft. in clear bearing, it shall be 4 in. in depth and 3 in. in thickness.

"(ii) *Purlins.*—He shall in the construction of the roof of a domestic building, public building, or building of the warehouse class, cause every purlin to be of not less than the size and strength following:—(*a*) If the purlins do not exceed 6 ft. 4 in. in clear bearing, and are not more than 6 ft. apart, each purlin shall be 5 in. in depth and 3 in. in thickness, or if more than 6 ft. and not more than 7½ ft. apart, each purlin shall be 5½ in. in depth and 3 in. in thickness, or if more than 7½ ft. and not more than 9 ft. apart, each purlin shall be 6 in. in depth and 3 in. in thickness. (*b*) If the purlins exceed 6 ft. 4. in. and do not exceed 8 ft. 4 in. in clear bearing, and are not more than 6 ft. apart, each purlin shall be 6 in. in depth and 4 in. in thickness, or if more than 6 ft. and not more than 7½ ft. apart, each purlin shall be 6½ in. in depth and 4 in. in thickness, or if more than 7½ ft. and not more than 9 ft. apart, each purlin shall be 7 in. in depth and 4 in. in thickness. (*c*) If the purlins exceed 6 ft. 4 in. and do not exceed 10 ft. 4 in. in clear bearing, and are not more than 6 ft. apart, each

purlin shall be 7 in. in depth and 5 in. in thickness, or if more than 6 ft. and not more than 7½ ft. apart, each purlin shall be 7½ in. in depth and 5 in. in thickness, or if more than 7½ ft. and not more than 9 ft. apart, each purlin shall be 8 in. in depth and 5 in. in thickness. (*d*) If the purlins exceed 10 ft. 4 in. and do not exceed 12 ft. 4 in. in clear bearing, and are not more than 6 ft. apart, each purlin shall be 8 in. in depth and 6 in. in thickness, or if more than 6 ft. and not more than 7½ ft. apart, each purlin shall be 8½ in. in depth and 6 in. in thickness, or if more than 7½ ft. and not more than 9 ft. apart, each purlin shall be 9 in. in depth and 6 in. in thickness. (*e*) If the purlins exceed 12 ft. 4 in. and do not exceed 14 ft. 4 in. in clear bearing, and are not more than 6 ft. apart, each purlin shall be 9 in. in depth and 6 in. in thickness, or if more than 6 ft. and not more than 7½ ft. apart, each purlin shall be 9½ in. in depth and 6 in. in thickness, or if more than 7½ ft. and not more than 9 ft. apart, each purlin shall be 10 in. in depth and 6 in. in thickness. (*f*) If the purlins exceed 14 ft. 4 in. and do not exceed 16 ft. 4 in. in clear bearing, and are not more than 6 ft. apart, each purlin shall be 11 in. in depth and 6 in. in thickness, or if more than 6 ft. and not more than 7½ ft. apart, each purlin shall be 11½ in. in depth and 6 in. in thickness, or if more than 7½ ft. and not more than 9 ft. apart, each purlin shall be 12 in. in depth and 6 in. in thickness. (*g*) If the purlins exceed 16 ft. 4 in. and do not exceed 18 ft. 4 in. in clear bearing, and are not more than 6 ft. apart, each purlin shall be 11 in. in depth and 7 in. in thickness, or if more than 6 ft. and not more than 7½ ft. apart, each purlin shall be 11½ in. in depth and 7 in. in thickness, or if more than 7½ ft. and not more than 9 ft. apart, each purlin shall be 12 in. in depth and 7 in. in thickness."

The conveying of rainwater from a roof to the drain is provided for in Urban Districts by § 74 of the Towns Improvement Clauses Act, 1847, which reads as follows :—

"The occupier of every house or building in, adjoining, or near to any street shall, within seven days next after service of an Order of the Commissioners for that purpose, put up and keep in good condition a shoot or trough of the whole length of such house or building, and shall connect the same either with a similar shoot on the adjoining house,

or with a pipe or trunk to be fixed to the front or side of such building from the roof to the ground, to carry the water from the roof thereof, in such a manner that the water from such house, or any portico or projection therefrom, shall not fall upon the persons passing along the street or flow over the footpath ; and in default of compliance with any such order within the period aforesaid, such occupier shall be liable to a penalty not exceeding 40s. for every day that he shall so make default."

§ 160 of the P.H.A., 1875, gives the Local Authority power to serve the Order upon the owner, and allows the occupier, if he carries out the work, to deduct the cost from the rent. In the district of a Rural Sanitary Authority this law does not apply, and the Local Authority should adopt the following bye-laws :—

"A.—Every person who shall erect a new building shall cause the roof or flat of such building to be so constructed that all water falling on such roof or flat shall be received in suitable gutters, shoots, or troughs, and shall thence be discharged into a pipe or trunk provided in pursuance of the bye-law in that behalf.

"B.—Every person who shall erect a new building shall cause a suitable pipe or trunk, extending from the roof of such building to the ground, to be fixed to the front or rear or to one of the sides of such building, and to be so connected with a gutter, shoot, or trough receiving any water that may fall on the roof, as to carry all such water therefrom without causing dampness in any part of any wall or foundation of such building."

Wherever a roof of an existing building is defective, the sanitary inspector will deal with it as with damp walls (see pp. 55–56), and declare it a nuisance and injurious to health, and cause an Order to Abate to be served on the owner.

The same course should be taken where any existing building in rural districts is without eaves gutters and down-pipes.

CHAPTER VII.

FLOORS, HEARTHS, AND STAIRCASES.

SECTION 157 of the P.H.A., 1875, was extended by the Amendment Act of 1890, "so as to empower every Urban Authority to make bye-laws with respect to . . . the structure of floors, hearths, and staircases, and the height of rooms intended to be used for human habitation," etc. The approved bye-law dealing with the construction of floors reads as follows :—

"FLOORS.—Every person who shall erect a new building shall, as regards the structure of every floor of such building, comply with such of the following rules as may be applicable to such building, that is to say :—

"*Domestic Buildings.—Joists.*—(i) He shall, in the construction of the floor of a domestic building, cause every common bearing joist to be of not less than the size and strength following :—(*a*) If the joist does not exceed 3 ft. 4 in. in clear bearing, it shall be 3 in. in depth and 3 in. in thickness. (*b*) If the joist exceeds 3 ft. 4 in. and does not exceed 5 ft. 4 in. in clear bearing, it shall be 3½ in. in depth and 3 in. in thickness. (*c*) If the joist exceeds 5 ft. 4 in. and does not exceed 7 ft. 4 in. in clear bearing, it shall be 4 in. in depth and 3 in. in thickness. (*d*) If the joist exceeds 7 ft. 4 in. and does not exceed 9 ft. 4 in. in clear bearing, it shall be 5 in. in depth and 2½ in. in thickness. (*e*) If the joist exceeds 9 ft. 4 in. and does not exceed 11 ft. 4 in. in clear bearing, it shall be 6 in. in depth and 2½ in. in thickness. (*f*) If the joist exceeds 11 ft. 4 in. and does not exceed 13 ft. 4 in. in clear bearing, it shall be 7 in. in depth and 2½ in. in thickness. (*g*) If the joist exceeds 13 ft. 4 in. and does not exceed 14 ft. 4 in. in clear bearing, it shall be 7 in. in depth and 3 in. in thickness. (*h*) If the joist exceeds 14 ft. 4 in. and does not exceed 16 ft. 4 in. in clear bearing, it shall be 8 in. in depth and 3 in. in thickness. (*i*) If the joist exceeds 16 ft. 4 in. and does not exceed 18 ft. 4 in. in

clear bearing, it shall be 9 in. in depth and 3 in. in thickness. (*j*) If the joist exceeds 18 ft. 4 in. and does not exceed 20 ft. 4 in. in clear bearing, it shall be 10 in. in depth and 3 in. in thickness. (*k*) If the joist exceeds 20 ft. 4 in. and does not exceed 22 ft. 4 in. in clear bearing, it shall be 11 in. in depth and 3 in. in thickness.

"*Trimming and Trimmer Joists.*—(*l*) A trimmer joist shall not receive more than six common joists, and the thickness of a trimming joist receiving a trimmer at not more than 3 ft. from one end, and of every trimmer joist receiving not more than six common joists, shall be 1 in. greater than the thickness hereinbefore specified for a common joist of the same bearing.

"*Beams.*—(ii) He shall, in the construction of the floor of a domestic building, cause every beam or girder of such floor, which is not used to support any wall, pier, or other similar structure, to be of not less than the size and strength following:—(*a*) If the beam exceeds 8 ft. and does not exceed 10 ft. in clear clearing, it shall be 10 in. in depth and 6 in. in thickness. (*b*) If the beam exceeds 10 ft. and does not exceed 12 ft. in clear bearing, it shall be 11 in. in depth and 7 in. in thickness. (*c*) If the beam exceeds 12 ft. and does not exceed 14 ft. in clear bearing, it shall be 12 in. in depth and 8 in. in thickness. (*d*) If the beam exceeds 14 ft. and does not exceed 16 ft. in clear bearing, it shall be 13 in. in depth and 9 in. in thickness. (*e*) If the beam exceeds 16 ft. and does not exceed 18 ft. in clear bearing, it shall be 14 in. in depth and 10 in. in thickness. (*f*) If the beam exceeds 18 ft. and does not exceed 20 ft. in clear bearing, it shall be 15 in. in depth and 11 in. in thickness.

"*Warehouse Buildings.—Joists.*—(iii) He shall, in the construction of the floor of a building of the warehouse class, cause every common bearing joist to be of not less than the size and strength following:—(*a*) If the joist does not exceed 3 ft. in clear bearing, it shall be 4½ in. in depth and 3 in. in thickness. (*b*) If the joist exceeds 3 ft. and does not exceed 4 ft. in clear bearing, it shall be 6 in. in depth and 2½ in. in thickness. (*c*) If the joist exceeds 4 ft. and does not exceed 5 ft. in clear bearing, it shall be 7 in. in depth and 2½ in. in thickness (*d*) If the joist exceeds 5 ft. and does not exceed 6 ft. in clear bearing, it shall be

7 in. in depth and 3 in. in thickness. (*e*) If the joist exceeds 6 ft. and does not exceed 7 ft. in clear bearing, it shall be 7½ in. in depth and 3 in. in thickness. (*f*) If the joist exceeds 7 ft. and does not exceed 8 ft. in clear bearing, it shall be 8 in. in depth and 3 in. in thickness. (*g*) If the joist exceeds 8 ft. and does not exceed 10 ft. in clear bearing, it shall be 9 in. in depth and 3 in. in thickness. (*h*) If the joist exceeds 10 ft. and does not exceed 12 ft. in clear bearing, it shall be 10 in. in depth and 3 in. in thickness. (*i*) If the joist exceeds 12 ft. and does not exceed 14 ft. in clear bearing, it shall be 11 in. in depth and 3 in. in thickness. (*j*) If the joist exceeds 14 ft. and does not exceed 16 ft. in clear bearing, it shall be 12 in. in depth and 3 in. in thick. ness. (*k*) If the joist exceeds 16 ft. and does not exceed 18 ft. in clear bearing, it shall be 13 in. in depth and 3½ in. in thickness. (*l*) If the joist exceeds 18 ft. and does not exceed 20 ft. in clear bearing, it shall be 14 in. in depth and 4 in. in thickness.

"*Trimming and Trimmer Joists.*—(*m*) A trimmer joist shall not receive more than six common joists, and the thickness of a trimming joist receiving a trimmer at not more than 3 ft. from one end shall be 1½ in. greater than the thickness hereinbefore specified for a common joist of the same bearing; and the thickness of a trimmer joist receiving not more than six common joists shall, for every such joist, be increased by ¼ in. additional to the thickness hereinbefore specified for a common joist of the same bearing.

"*Beams.*—(iv) He shall, in the construction of the floor of a building of the warehouse class, cause every beam or girder of such floor which is not used to support any wall, pier, or other similar structure, to be of not less than the size and strength following:—(*a*) If the beam exceeds 8 ft. and does not exceed 10 ft. in clear bearing, it shall be 12 in. in depth and 11 in. in thickness. (*b*) If the beam exceeds 10 ft. and does not exceed 12 ft. in clear bearing, it shall be 13 in. in depth and 12 in. in thickness. (*c*) If the beam exceeds 12 ft., and does not exceed 14 ft. in clear bearing, it shall be 14 in. in depth and 13 in. in thickness. (*d*) If the beam exceeds 14 ft. and does not exceed 16 ft. in clear bearing, it shall be 15 in. in depth and 14 in. in thickness. (*e*) If the beam exceeds 16 ft. and does not exceed

18 ft. in clear bearing, it shall be 18 in. in depth and 15 in. in thickness. (*f*) If the beam exceeds 18 ft., and does not exceed 20 ft. in clear bearing, it shall be 24 in. in depth and 15 in. in thickness.

"*Public Buildings.*—(*v*) He shall, in the construction of every floor of a public building, not being a floor in a small room intended to be used for private purposes, or of an ante-room, cause every bearing joist and every beam or girder of such floor which is not used to support any wall, pier, or other similar structure, to be of a sufficient and proper depth and thickness for the purpose for which it is intended, such depth and thickness, in every case where such joists are laid and fixed at distances of not more than 12 in. apart, and where such beams are laid and fixed at not more than 8 ft. apart, measured in either case from the middle of one joist or beam to the middle of the next or to the nearest wall, being not less than the thickness hereinbefore prescribed for joists and beams of domestic buildings, and in every other case the depth and thickness being one-fifth greater than the depth and thickness so prescribed."

Then follow general regulations affecting the construction of both roofs and floors :—

"*General Rules.*—The requirements of the preceding bye-laws relating to roofs and the structure of floors shall be subject to the following rules, that is to say :—

(1) The sizes and strengths hereinbefore prescribed apply only to beams, joists, purlins, and rafters of any species of fir or pine of sound and good quality, and if any other kind of wood is used the size and strength of every beam, joist, purlin, and rafter shall be such as may be adequate to secure due stability.

(2) The sizes prescribed for the timbers mentioned in the foregoing rules shall represent the least size and strength which any such timber may have at any part.

(3) Every beam, joist, purlin, and rafter shall be laid and fixed on edge, its greatest side being in a vertical position, or nearly so, as may be requisite, and when laid and fixed in such position, the distance between the upper and lower surfaces thereof shall, for the purposes of this bye-law, be deemed to be the depth thereof.

(4) In calculating the size and strength required for any beam or other timber intended to be of a strength equal to or greater than that of any particular beam or other timber of the same length and of the dimensions specified in the bye-law in that behalf, the following method shall be adopted: In both cases the number of inches in the depth of such beam or other timber shall be multiplied by itself and the product shall be multiplied by the number of inches in the breadth. The number thus obtained shall be taken to represent the strength of such beam or other timber.

(5) The rules relating to joists and beams in floors are applicable only to floors formed of joists laid on edge in the ordinary way and covered with boards.

(6) In the case of a framed floor, or of a floor formed with beams at short distances apart, and covered with battens, deals, or planks, without joists, the several timbers of such floor shall be of such size and strength as may be adequate to secure due stability.

"(7) The rules relating to joists and beams in floors are applicable only to joists laid at a distance of not more than 15 in. apart, measured from the middle of one joist to the middle of the next or to the nearest wall, and to beams laid at a distance of not more than 10 ft. apart, measured from the middle of one beam to the middle of the next or the nearest wall. And joists and beams, not exceeding the dimensions specified in the foregoing rules, shall be laid and fixed at not more than the aforesaid distances apart, namely, 15 in. and 10 ft. respectively: (i) Provided that in the case of a floor formed of joists or beams of greater dimensions than the respective dimensions specified, such joists or beams may be laid and fixed at a proportionately greater distance apart than 15 in. and 10 ft. respectively; and (ii) In the case of a floor formed of joists or beams of less dimensions than the respective dimensions specified, or of timber of inferior quality, such joists or beams shall be laid and fixed at a proportionately less distance apart than 15 in. and 10 ft. respectively.

"(8) In the case of a floor in which any joist or beam is of a length for which no provision is made in the foregoing rules, such joist or beam shall be of such size and

strength as may be adequate to secure due stability, and in any case where herring-bone strutting is constructed between joists, the size and strength of such joists may be reduced by such an amount as is equivalent to the strength represented by the strutting.

"(9) The rules relating to rafters and purlins in roofs are applicable only to roofs formed of rafters and purlins laid in the ordinary way and covered with slates of the usual kind.

"(10) In the case of a roof formed of coupled rafters or of rafters laid horizontally, or in the case of a boarded roof covered with slates, or in the case of a roof covered with glass, lead, tiles, stone, iron, cement, or other material not being slates of the usual kind, the several timbers of such roof shall be of such size and strength as may be adequate to secure due stability.

"(11) The rules relating to rafters and purlins in roofs are applicable only to rafters laid at a distance of not more than 15 in. apart, measured from the middle of one rafter to the middle of the next or to the nearest wall, and to purlins laid at a distance of from 6 to 9 ft. apart, measured from the middle of one purlin to the middle of the next or to the ridge or to the bearing upon the wall. And rafters and purlins not exceeding the dimensions specified shall be laid and fixed at not more than the aforesaid distances apart, namely, 15 in. and 9 ft. respectively: Provided that—(i) In the case of a roof formed of rafters or purlins of greater dimensions than the respective dimensions specified, such rafters or purlins may be laid and fixed at a proportionately greater distance apart than 15 in. and 9 ft. respectively. (ii) In the case of a roof formed of rafters or purlins of less dimensions than the respective dimensions specified, such rafters or purlins shall be laid and fixed at a proportionately less distance apart than 15 in. and 6 ft. respectively.

"(12) In the case of a roof in which any rafter or purlin is of a length for which no provision is made in the foregoing rules, such rafter or purlin shall be of such size and strength as may be adequate to secure due stability."

Cellar floors should be impervious to wet, non-porous, easily kept clean, smooth, and inodorous. Where the M.B.L. No. 11 has been carried out, and there is a layer of concrete

or asphalt all over the site, there exists only a necessity for a covering layer which shall fulfil the other conditions. This may be a coating of 1 in. thick of portland cement and granite dust, in equal proportions, and carefully trowelled until the surface is as smooth and hard as polished slate; or the coating may be a layer of vitrified bricks or tiles set in hydraulic mortar or portland cement; or good hard non-porous flags; or a 1-in. layer of rock-asphalt (tar asphalt is too odorous); or wood-block flooring, where the blocks are well seasoned and laid in asphaltic cement on the concrete. Wood-blocks are, however, somewhat dangerous in a basement, on account of the possibility of dry-rot finding a lodgment there, and rendering it necessary to have the whole floor taken up and removed.

Sometimes it is necessary to lay a basement floor, where

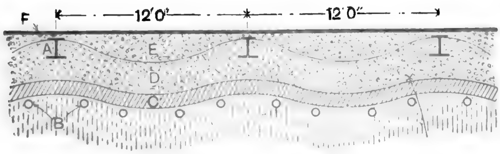


Fig. 88.—Basement Floor Laid below Mean Water Level.

the ream water level is above the floor level; in which case special precautions must be taken. From Fig. 88—illustrating the construction of a floor in Canning Town, laid several feet below water-level, where the upward pressure on the floor was between 600 lb. and 700 lb. per square foot—it will be seen that rolled iron joists A, 15 in. by 12 in., were laid at 12-ft. centres, being pinned into the wall at each end; the surface of the ground was trimmed to the requisite level, earthenware drain-tubes B being inserted in the porous clay and mud to carry off the water during the execution of the work; on this was laid clay puddle C, and the concrete inverted arches D were then put in. After they had set, the floor was levelled up with concrete E, and covered with asphalt F; 5-in. rolled iron joists were also placed about 4 ft. apart on the bottom flange of the 15-in. by 12-in. joists. G shows hoop-iron tarred and laid in concrete. There are many other expedients for dealing with similar problems.

The living-rooms of a house are generally those on the ground-floor, and for these the ordinary boarded floor is the most comfortable. The boards should be tongued and grooved, well seasoned, and well laid, especially when there is no cellar below.

In one respect the ordinary floor is exceedingly insanitary: it is a convenient place for the gas-pipes; it is sometimes, though rarely, used for purposes of ventilation; but it is otherwise little cared for, and forms a happy hunting ground for the mice, if not for more objectionable vermin. At present the sanitary inspector cannot deal with it, unless and until it becomes bad enough to be dealt with under the "nuisance" section of the P.H.A., 1875. It has been

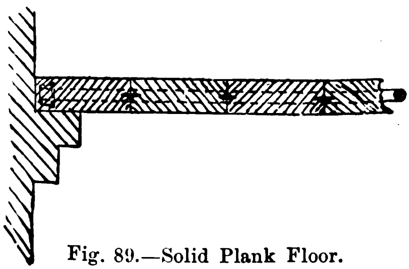


Fig. 89.—Solid Plank Floor.

suggested to fill the space with slag-wool, with sterilised sawdust, peat moss, etc.

Mr. Joseph Corbett, M.San.I., in a paper before the Sanitary Congress at Bolton, in 1887, advocated a floor made of planks 3 in. thick, tongued, grooved, and bolted together. He said that the floor of each room could be completely prepared in the workshop; the separate planks being machine-planed, squared, and grooved; two 1-in. bolt-holes bored laterally through each plank; hoop-iron tongues inserted in the grooves; bolts inserted from side to side of the set of planks and screwed up tight; the surface dressed off, and the complete slab of flooring conveyed to its place and laid down on salient courses in the room walls prepared to receive it (see Fig. 89).

In many cases it would be more economical to make each room floor in three pieces, joined together by an under

board and coach screws. The shrinkage could be easily taken up by tightening the through bolts. The chink round the walls would be flushed with cement; and thus a strong, warm, draught-proof, vermin-proof floor would be made at a cost not exceeding that of a common floor and plaster ceiling. Such plank-floors are more sound-proof than ordinary floors, and are very nearly fire-proof. Where the rooms were wider than 12 ft., the planks would have to be 3½ in. or 4 in. deep to be able to span the increased distance. There are two other economies resulting from their use; they save one step in each flight of stairs, and in the height of the walls; and being put into position as soon as the supporting salient courses are set, they may be protected by boards, and used as scaffolding, saving the cost of the latter.

Many other materials for floors have been suggested and used, but not often in the average dwelling-house, and therefore it will be of no use to discuss them; steel joists, however, may be mentioned, and brick arches, or concrete, or tile arches, either with or without an upper surface of boards, cork, papier-mâché, etc. Often it happens that, owing to the shrinkage of floor boards, a nasty crevice is left between them, admitting draughts, harbouring dirt, vermin, and infection, and becoming a danger to health. These crevices may either be filled up with strips of wood, or with one of several compositions, such as thin glue and sawdust, paste and sawdust, plaster-of-Paris, sawdust and water, oakum, etc. One, however, that is most highly recommended is to thoroughly soak old newspapers in paste made of 1 lb. of flour, 3 quarts of water, a tablespoonful of alum, the paste to be thoroughly boiled; when properly made it will be as thick as putty, and the filling will harden like papier-mâché.

While considering floors and their facilities for becoming dirt receptacles, we are reminded of skirtings. On this point the P.H.A. are silent, and consequently there is no power to make bye-laws on the subject. There is ample room for a regulation to prevent the leaving of spaces behind skirtings; these, even more than the hollows in floors, are the haunts of mice and other vermin (see Fig. 90). The plaster of the walls should be carried right down to the flooring boards; in the inferior rooms of houses, such as kitchens, smaller

bedrooms, etc., the skirting might with advantage be formed of portland cement (see Fig. 91).

There are other points upon which the Acts are silent. Plaster for walls is not mentioned, and, unless a town has a private Act of Parliament including this word, a builder may use any material which will stick upon the walls, providing it is clean. If it is foul, the sanitary inspector may put into force the "nuisance" clause of the 1875 Act. Ceilings are not mentioned, and a builder may use timber of any strength, if only it will not fall down. Wall-plates, ridge pieces, cornices, and many other portions of a house are omitted, as is also the size of rooms.

The next item with respect to which bye-laws can be

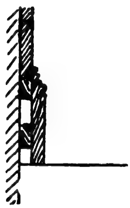


Fig. 90.—Ordinary Skirtings.

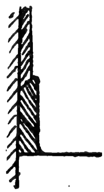


Fig. 91.—Skirting Made of Portland Cement.

made is hearths, and the clause which has been approved is as follows :—

"*With respect to Hearths.*—5. A person who shall erect a new building shall place and fix in front of every chimney-opening in such building a proper hearth of stone, slate, bricks, tiles, or other incombustible substance, at the least 6 in. longer at each end than the width of such opening, and projecting not less than 18 in. distant from the chimney-breast. He shall cause such hearth to be laid at the level of the floor of the room in which such chimney-opening is situated, and to be borne wholly upon stone or iron bearers, or upon a brick trimmer arch (see Fig. 92), and bedded wholly on brick, stone, or other incombustible substance, extending to a depth of 7 in. at the least beneath the upper surface of the hearth, provided that in the lowest storey the hearth may be bedded on the solid ground."

This regulation, it will be seen, is more for the prevention of fires than for the purposes of health.

With regard to staircases the 1890 Act gives a Local Authority power to make complete bye-laws as to the structure and materials. The bye-laws drawn up by Messrs. Knight & Co. read as follows :—

" *With respect to Floors and Staircases.*—9. Every person who shall erect a new public building shall construct the floor of every lobby, corridor, passage, and landing, and every flight of stairs in any staircase in such building, and

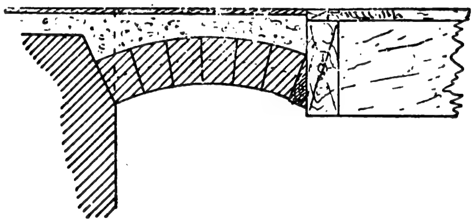


Fig. 92.—Section through Hearth showing Brick Trimmer.

all the supports of every such floor and flight of stairs, of stone or other incombustible material, and of adequate strength. Provided always, that the foregoing requirements shall not apply to the floor of a lobby, corridor, passage, or landing, or to any flight of stairs intended to be used otherwise than as means of access to any part of a public building intended to be used for any public purpose.

" 9A. Every person who shall erect a new public building shall construct the floor of every lobby, corridor, passage, and landing therein, which is not intended solely as a means of access to any private apartment, and all the supports of every such floor, of stone or other incombustible or fire-resisting materials, and of adequate strength.

" 9B. Every person who shall erect a new public building or a new building of the warehouse class, and shall construct any staircase therein, shall cause every flight of stairs in such staircase to be properly constructed of sound and suitable materials, and to be securely fixed and of adequate strength.

He shall in the case of a public building cause every flight of stairs in such staircase which is not intended solely as a means of access to any private apartment to be constructed of incombustible materials, and carried by supports of incombustible materials, and to be furnished on each side with a sufficient handrail, properly and securely fixed. He shall in the case of a public building cause every flight of stairs in such staircase which is intended solely as a means of access to any private apartments to be provided with a sufficient handrail, properly and securely fixed.

"9c. Every person who shall erect a new building which shall be intended for use as a dwelling-house for separate families, and which shall contain more than 125,000 cub. ft., shall cause the floor of every landing, corridor, passage, and lobby, and every flight of stairs in any staircase in such building, and all the supports of every such floor and flight of stairs to be constructed of stone or other incombustible and fire-resisting material.

"9D. Every person who shall erect a new domestic building containing separate sets of chambers or offices or rooms constructed or intended or adapted to be tenanted by different persons, and which shall exceed 50,000 ft. in cubical extent, shall construct the floor of every lobby, corridor, passage, and landing, and every flight of stairs in any staircase in such building, and all the supports of every such floor and flight of stairs of stone or other fire-resisting material and of adequate strength, and shall cause the principal staircase and landings of such building to be enclosed with walls, not less than 9 in. in thickness, constructed of good hard, sound, well-burnt bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together. (*a*) With good mortar compounded of good fresh-burnt lime and clean, sharp sand, or of good fresh-burnt lime and a mixture of 1 part of sand and 2 parts of burnt ballast, broken bricks, stones, furnace or forge ashes, ground sufficiently fine and properly mixed with the lime in the proportion of 1 part of lime to 3 parts of sand or grit; or (*b*) with good cement; or (*c*) with good cement mortar, compounded of good cement, mixed with clean, sharp sand or grit as aforesaid in the proportion of 1 part of cement to 4 parts of sand or grit. He shall also construct

the floor of every scullery and water-closet above the ground floor of concrete of other impermeable material.

"9E. Every person who shall erect a new domestic building and shall construct any staircase therein shall comply with the following requirements: that is to say—

"(1) He shall cause the woodwork of every flight of stairs in such staircase to be of not less than the following thicknesses, viz.:—(*a*) The strings shall not be less than $1\frac{1}{4}$ in. in thickness. (*b*) The treads shall not be less than 1 in. in thickness. (*c*) The risers shall not be less than $\frac{3}{4}$ in. in thickness.

"(2) He shall cause the treads to be not less than 8 in. in width, measured horizontally, from face of riser to face of riser, and the risers to be not more than 9 in. in height, measured vertically from top of tread to top of tread.

"(3) He shall cause such staircase to be provided with a sufficient handrail, properly and securely fixed.

"9F. Every person who shall construct a room for habitable purposes over a stable shall so construct the floor of such room that in every part not occupied by a joist or girder there shall be a layer of concrete pugging of good quality, or of other solid material at least 3 in. in thickness, finished smooth upon the upper surface and properly supported."

The following suggestions are worthy of consideration; they are based on the "Notes on Building Construction" (Rivington's):—The dimensions of staircases and steps are regulated by the class of property and the purposes for which they are intended. The angle of ascent for a stair depends upon the total height to be gained between the floors, and the space that can be afforded in plan. The speculative builder will naturally be tempted to make both of these as small as he possibly can. The wider the step, the less the rise should be, as steps which are both wide and high require a great exertion to climb, and are consequently insanitary to those whose constitutions incline to weakness of heart and shortness of breath. Authorities differ slightly as to the proportion between the tread and riser. The following table is given in Newland's "Carpenter's and Joiner's

Assistant," and the subject is discussed in Adams' "Building Construction" (Cassell & Co.) :—

Tread	6 in.	Riser	8½ in.
,,	7 ,,	,,	8 ,,
,,	8 ,,	,,	7½ ,,
,,	9 ,,	,,	7 ,,

The following rule is often adopted for steps of the dimensions required in ordinary practice :—Width of tread × height of riser = 60 to 65 in. The rule adopted in France, where they have given great attention to the subject, is as follows :— "Inasmuch as on the average human beings move horizontally 2 ft. in a stride, and as the labour of rising vertically is twice that of moving horizontally, the width of the tread, added to twice the height of the riser, should be equal to 2 ft." The tread of a step should, however, never be less than 9 in., even for the commonest stair; and the maximum height of a riser should never be greater than 9 in. Flights of stairs should, when possible, consist of not more than twelve or thirteen steps, after which there should be a landing.

This same section of the P.H.A. Amendment Act, 1890, which has just been considered, after empowering Local Authorities to make bye-laws "with respect to the structure of floors, hearths, and staircases," proceeds to add, "and the height of rooms intended to be used for human habitation." The L.G.B. has not promulgated any M.B.L. on the subject, but in December, 1891, the year after the passing of the Act, the Board published a "Memorandum concerning a height to be appointed, under the provisions of the P.H.A. Amendment Act, 1890, § 23, by Sanitary Authorities, for rooms to be used for human habitation"; and a bye-law has been drawn up by Messrs. Knight & Co. as follows :—

No. Q. "*With respect to the Height of Rooms intended to be used for Human Habitation.*—Every person who shall erect a new building, and shall construct any room therein so that it may be used for human habitation, shall comply with the following requirements: If such room is not intended to be used as a sleeping-room, he shall construct such room so that it shall be not less in any part thereof than 9 ft. in height. If such room is intended to be used

as a sleeping-room, and not an attic or a room in the roof of such building, he shall construct such room so that it shall be not less in any part than 9 ft. in height. If such room is intended to be used as a sleeping-room, and is an attic or a room in the roof of such building, he shall construct such room so that it shall be not less in any part than 5 ft. in height, and so that it shall to the extent of *two-thirds* of the superficial area of the floor be of a height of not less than 9 ft."

The Memorandum remarks that it will seldom or never be requisite to appoint by bye-law any maximum height for habitable rooms. Under ordinary conditions low-ceiled rooms are comparatively more difficult to ventilate than rooms of greater height; and, as regards living-rooms, the fact is so far generally recognised that they are usually built of a sufficient height. It is more particularly in the case of sleeping-rooms that builders fail to act upon this knowledge; and yet it is in sleeping-rooms that adequate height is of the greatest importance, because the occupants are not able during sleep to vary the conditions of air-movement through the room.

Bye-laws on this height question, being of chief importance for sleeping-rooms, are of especial importance in the case of domestic buildings, where rooms may, in the ordinary course of events, be occupied during the night by a number of persons. The provision of adequate breathing space for all the occupants of a room will be materially facilitated or hindered, according as the height of the room is varied. A room may provide sufficient floor space for the wants of a given number of persons; but whether this number of persons will have enough breathing space to keep them in health will depend upon the height of the room. If, for example, there is just enough breathing space when the height is 8 ft. or 9 ft., it is obvious that there will not be enough when the height is only 7 ft. The requisite space can only be obtained, in rooms of insufficient height, by reducing the number of persons occupying the room; that is, by giving the several occupants a floor area in excess of what would otherwise be sufficient for them. But too many people reckon a room's capacity by its floor area only, without regard to its height, and in this way rooms of in-

sufficient height operate in serious measure to foster "overcrowding."

Having in view these considerations, the L.G.B. give notice that, all due regard being had to economy as well as to health, the minimum height had better be 9 ft.; in some cases the Board may approve of bye-laws fixing 8½ ft. or 8 ft. as the minimum, but they prefer 9 ft., and in no case

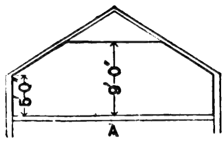


Fig. 93.—Averaging Height of Room.

will they ever approve of a less height than 8 ft. over the total area of the room.

In the case of rooms in the roof of a house, where very often the height of the room is not uniform, and where there is a much greater temptation for the builder to economise, there is just the same reason as in the case of other rooms

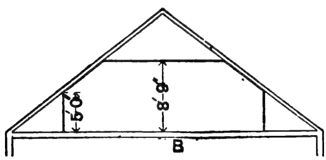


Fig. 94.—Averaging Height of Room.

for securing proper height for them; the last clause of the above-quoted bye-law is intended to cover this, and to ensure the mean height of the room being not less than 8 ft. This can be arranged with roofs of different shapes as shown at Figs. 93 to 95. With an attic 25 ft. wide, having the floor 5 ft. below the level of the eaves, and the roof pitched at an angle of 33°, it will suffice if the highest point of the ceiling is 9 ft. above the floor, which, it will be found, allows this height over one-half of the superficial area of the room (Fig. 93). When the floor is on a level with the eaves,

and the roof forms with it an angle of 38°, ashlaring 5 ft. in height must cut off the bottom angles, when an extreme height of 8 ft. 9 in. over three-fifths of the area of a room 25 ft. wide will provide the minimum average over the whole space (Fig. 94). With a mansard—or, as it is sometimes called, a Dutch—roof, the angles being respectively 57° and 132°, with 5-ft. ashlaring, and with a portion of the ceiling equal to five-sixths the floor area 8 ft. 4 in. in height, a mean height of 8 ft. over a 25-ft. room will be attained (Fig. 95).

The floor area of rooms is not mentioned in any of the P.H.A. Many writers on sanitary engineering hold that the size of the room regulates itself, being according to the value of land, the depth of the owner's pocket, the probable income that can be obtained as rent, etc. It will, however, be generally admitted that the living-room of a house should

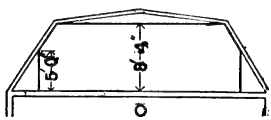


Fig. 95.—Averaging Height of Room.

have sufficient cubic contents to provide for the family living in it; and as the height of the storey is never excessive the floor area ought not to be too strictly limited. It will be shown later that the M.B.L. provide for a sufficiently wide street in front, a fair-size back yard, and an ample distance between the back of the house and the opposite property. A builder, having to leave such a large quantity of land unbuilt upon, is all the more tempted to reduce the area of the rooms within the house; and a working man and his family are thus half-suffocated in a small room, whilst a large air-space, which they cannot enjoy, is left around the house.

The size of habitable rooms no more regulates itself than the width of streets, the structure of walls, or the provision of damp-proof courses regulate themselves. The average number in a family is five persons, and the minimum

space in a bedroom per head should be 300 cub. ft.; taking the same figure for a living-room, namely, 1,500 cub. ft., and dividing by a minimum height of 9 ft., the floor area should be 166 super. ft. The minimum size for the principal or living-room in a house should be 144 super. ft. in area; less than this is conducive to overcrowding, and injurious to health.

There is one more point included in the P.H.A. Amendment Act, 1890, namely, with respect to "the paving of yards and open spaces in connection with dwelling-houses." Messrs. Knight & Co. have drawn up two bye-laws on this subject; the first applying to houses already erected, and where the yards are not paved; the second applying to the yards of new houses. The materials mentioned have been discussed earlier, and it will not be necessary to go through them again. The bye-laws read as follows:—

"11. The owner of every dwelling-house in connection with which there is any yard or open space, shall, where it is necessary for the prevention or remedy of insanitary conditions that all or part of such yard or open space shall be paved, forthwith cause the same to be properly paved with a hard, durable, and impervious pavement of flagging or paving bricks evenly and closely laid upon a sufficient bed of good concrete, mortar, or other suitable material, and properly jointed, or with good cement concrete, or with good asphalt on a proper foundation, and so sloped to a properly constructed channel as effectually to carry off all rain or waste water therefrom.

"12. Every person who shall erect a new dwelling-house shall cause not less than 150 sq. ft. of any open space provided in connection therewith to be paved with hard, durable and impervious pavement of flagging or paving bricks, evenly and closely laid upon a sufficient bed of good concrete, mortar, or other suitable material, and properly jointed, or with good cement concrete, or with good asphalt on a proper foundation, and so sloped to a properly constructed channel as effectually to carry away all rain and waste water that may fall thereon. He shall cause such paving to be so arranged that it shall adjoin the external wall in the rear or at the side of the dwelling-house, that wherever practicable it shall extend throughout to a distance of 10 ft. from the

said wall, and that, subject to this last-mentioned requirement, it shall extend as nearly as conveniently may be to the full width of the open space. For the purposes of this bye-law, the expression 'width' means, in the case of paving in the rear, a measurement taken parallel to the rear external wall of the dwelling-house, and, in the case of paving at the side, a measurement taken at right angles to the side external wall on which such paving may abut."

CHAPTER VIII.

AIR SPACE AND VENTILATION.

THE next subject on which a Local Authority is empowered (by § 157 of the P.H.A., 1875) to make bye-laws is : "(3) With respect to the sufficiency of the space about buildings to secure a free circulation of air, and with respect to the ventilation of buildings."

It has already been mentioned that the first P.H.A. was the result of an inquiry, held in 1842 and subsequent years, into the sanitary state of large towns and populous districts. One of the points brought out in that inquiry, and one which is well known to all who live in towns, was the practice of building houses in courts 10 ft. or 12 ft. wide, generally back to back, while the entrance to each court is a tunnel or covered passage 3 ft. wide under the upper storeys of the houses in the main street. Fig. 96 gives a typical example of this arrangement. With a few notable exceptions, Sanitary Authorities in England will not allow back-to-back houses to be erected, and the M.B.L., wherever adopted, effectually prevent this—first, by requiring a comparatively wide space in front; and, secondly, by insisting upon a yard of a certain area at the back, and also a minimum distance from the opposite property at the rear of the house.

The following is the M.B.L. requiring a space in front of new buildings :—

M.B.L. No. 52 : "Every person who shall erect a new domestic building shall provide in front of such building an open space, which, measured to the boundary of any lands or premises immediately opposite, or to the opposite side of any street which may not be less than 24 ft. in width at the point where such building may front thereon, shall, throughout the whole line of frontage of such building, extend to a distance of 24 ft. at the least; such distance being measured in every case at right angles to the external

face of any wall of such building which shall front or abut on such open space. Where a new domestic building may be intended to front on a street laid out before the confirmation of these bye-laws, and of a less width than 24 ft., the person

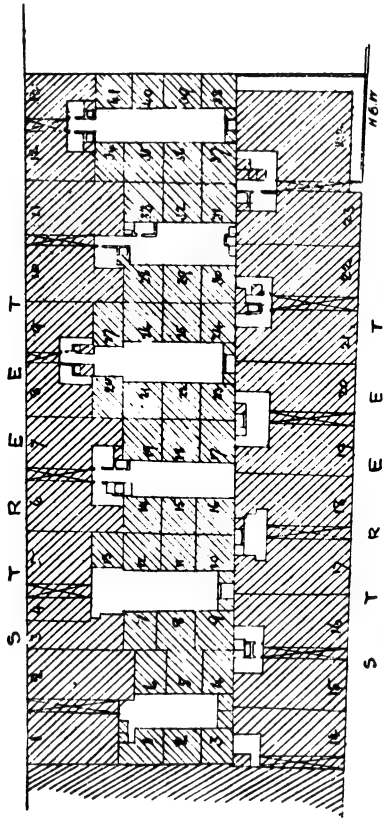


Fig. 96.—Back-to-back Houses in Courts, Approached by Covered Passages.

who shall erect such building shall provide in front thereof an open space, which, measured to the opposite side of such street throughout the whole line of frontage of such building, shall extend to a distance equal at least to the width

of such street, together with one-half of the difference between such width and 24 ft. Any open space provided in pursuance of this bye-law shall be free from any erection thereon above the level of the ground, except any portico, porch, step, or other like projection from such building, or any gate, fence, or wall not exceeding 7 ft. in height. A person who shall make any alteration in or addition to any building or who shall erect any new building shall not, by such alteration, addition, or erection, diminish the extent of open space provided in pursuance of this bye-law in connection with a building, or in any other respect fail to comply with any provision of this bye-law."

It will be noticed that the space in front shall extend 24 ft. from the wall of the house; but this is when that space is not used as a carriage-road, for another bye-law provides that every new street intended for use as a carriage-road shall be at the least 36 ft. wide. It is further provided that every street above 100 ft. long shall be constructed as a carriage-road, and therefore at least 36 ft. wide; also that any new street not intended to be used as a carriage-road, and being less than 100 ft. in length, to be 24 ft. wide at the least. Although power is given to erect houses with only 24 ft. in front of them, this can only happen in the older parts of towns, where large houses standing in gardens are demolished, and the space is utilised for cottage houses. In the newer parts of the town, houses will be erected along the sides of streets 36 ft. wide, and thus a greater air-space is provided than that set out in the above bye-law (No. 52).

The next M.B.L. (No. 53) provides for the sufficiency of air-space at the rear, and reads thus:—

M.B.L. No. 53: "(1) Every person who shall erect a new domestic building shall provide in the rear of such building an open space exclusively belonging to such building, and of an aggregate extent of not less than 150 sq. ft., and free from any erection thereon above the level of the ground, except a water-closet, earth-closet, or privy, and an ashpit, constructed respectively in accordance with the bye-laws in that behalf. In the case of a domestic building not being a building intended and adapted to be used exclusively as a stable, he shall cause such open space to extend through-

out the entire width of such building, and he shall cause the distance across such open space from every part of such building to the boundary of any lands or premises immediately in the rear of the site of such building, to be not less in any case than 10 ft. If the height of such building be 15 ft., he shall cause such distance to be 15 ft. at the least. If the height of such building be 25 ft., he shall cause such distance to be 20 ft. at the least. If the height of such building be 35 ft. or exceed 35 ft., he shall cause such distance to be 25 ft. at the least. In any case where, by reason of the exceptional shape of the site of such building, the minimum distance across the open space required by this bye-law cannot be obtained throughout the entire width of such building, it shall suffice if the mean distance across such open space be not less than the minimum distance so required.

"Provided that (1) Where it is intended to erect a new domestic building on a site abutting on two or more streets; or (ii) where it is intended to re-erect a domestic building in a street laid out before the confirmation of these bye-laws; and it is impracticable to comply with the preceding requirements of this bye-law, the said requirements shall be deemed to be satisfied by the provision at the rear or on one side of the site other than the front of such building of an open space exclusively belonging to such building of an extent of at least 150 sq. ft., or, in the case of a re-erection of a domestic building, of an extent not less than that of any open space previously provided in connection with such building and in no case less than 100 sq. ft., which shall be free from any erection thereon except a water-closet or earth-closet and an ashpit, and subject to the following conditions:—(*a*) The open space shall extend throughout at least 10 ft. of the width or depth of such building, and the mean distance across such open space, measured from the opposite part of such building, to the nearest boundary of any street, lands, or premises immediately adjoining such open space shall be in no case less than 10 ft.; and (*b*) if the said open space does not abut on a street it shall be connected with a street by means of a passage or other similar opening so arranged as to be capable at all times of affording a free

circulation of air between the open space and such street.

"(2) (*a*) This bye-law shall not apply so as to require any open space to be provided in the rear of any domestic building other than a dwelling-house where such building, not being a stable, is appurtenant to a dwelling-house, and is not of a greater height than such dwelling-house, and abuts on the open space provided in the rear of such dwelling-house, and where the open space so provided is sufficient to comply with the requirements of this bye-law; or where such building being a stable has adjoining and exclusively belonging to it an open space of not less than 150 sq. ft. in extent. (*b*) Where any such building, not being a stable, is of a greater height than the dwelling-house to which it is appurtenant, the foregoing exemption shall not apply, unless the open space in the rear of such dwelling-house is sufficient to comply with the requirements of this bye-law in respect of a dwelling-house of the height of the building so appurtenant.

"(3) A person who shall make any alteration in or addition to any building, or who shall erect any new building, shall not, by such alteration, addition, or erection, diminish the extent of open space provided in pursuance of this bye-law in connection with a building, or in any other respect fail to comply with any provision of this bye-law.

"(4) For the purposes of this bye-law the height of a building shall be measured upwards from the level of the ground over which such open space shall extend to the level of half the vertical height of the roof or to the top of the parapet, whichever may be the higher."

Fig. 96 shows the necessity for this regulation. The houses facing the two streets were apparently erected first, and with adequate air-space between their backs. A later owner then crammed as many back-to-back houses as possible into this open space, bringing about the state of things mentioned in the second paragraph of this chapter. Needless to say, this area has since been cleared as insanitary. Much information on this subject can be obtained from a Report to the L.G.B. on Back-to-back Houses, by Dr. Barry and Mr. T. Gordon Smith, F.R.I.B.A., dated February, 1888 (Wyman and Sons, London).

It is not now permissible to mass so many persons on the acre. On reference to Fig. 96 it will be found that there are forty-one houses back to back, each house (including its own portion of the court) occupying 30 sq. yd., and allowing four persons to each house, the almost incredible total is 564 persons per acre; even when the number of occupants per house is reduced to three, there are 484 persons to the acre. Taking the area of the whole block and half the width of the adjacent streets, there are forty-one houses with, say, three occupants each, and twenty-four houses with, say, five each, or a total of 243 persons on 3,870 sq. yd., or 304 persons per acre, which is still phenomenal.

Mr. J. P. Williams-Freeman, writing some years back "On the Effect of Town Life on the General Health, with especial Reference to London," said, "The average density of 'urban' London is ninety-nine persons per acre ('suburban' London only having twenty-two). In urban London the minimum density is that of the sub-district of Norwood in Lambeth, which is eighteen to the acre; and the greatest is found in St. Andrew's, Eastern, Holborn, a sub-district of 33 acres, with the extraordinary density of 324 persons per acre. In the year 1889, a district in Ancoats, Manchester, 32 acres in extent, and with an estimated population of 5,654, was, according to an 'official representation' made by Dr. Tatham, M.O.H., 'unfit for habitation.' The evils connected with such houses, courts, and alleys, and the sanitary defects in each area, could not be effectually remedied otherwise than by an improvement scheme for the re-arrangement and reconstruction of the streets and houses within the area. The death-rate over the whole district at the time was more than fifty per 1,000; in the courts it exceeded eighty, and in one street was over ninety. This population works out at $176\frac{2}{3}$ per acre. The population in a district near that indicated by Fig. 96 containing $24\frac{3}{4}$ acres, was, in 1891, 5,243, or 220 per acre; the number of houses was 1,117, or forty-five per acre, with an average of $4\frac{3}{4}$ persons per house."

The very smallest houses it is possible to build under the foregoing bye-laws, namely, those containing only one room downstairs, and one above, with half of a 36-ft. street in front and a yard of 150 sq. ft., will occupy 84 sq. yd. of

land (see Fig. 97) ; this will give fifty-seven houses, or 171 persons per acre at three per house. A house containing two rooms on the ground floor (see Fig. 98), with similar open spaces, will occupy about 100 sq. yd. of land ; this will equal forty-eight houses, and at four persons per house will give a density of 192 persons per acre. A house containing two rooms and a scullery on the ground floor, and with an attic bringing it above the 25 ft. in height (see Fig. 99), will occupy about 125 sq. yd., being thirty-nine houses

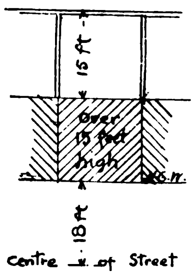


Fig. 97.—House of Smallest Possible Type.

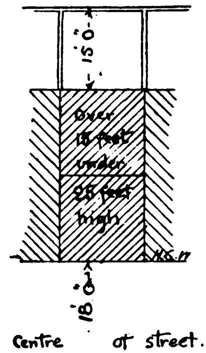


Fig. 98.—Four-roomed House.

per acre, or a density, at five per house, of 195 to the acre.

As the size of the house increases, so, proportionately, there are fewer houses, and consequently a smaller population, per acre ; but it must be remembered that in these calculations the lungs or breathing-places of the town—that is, the parks and recreation grounds—have been omitted. It will be seen that much depends upon the arrangement of the buildings ; it is quite possible to house 200 persons per acre in accordance with the M.B.L. and with the most perfect sanitary arrangements ; on the other hand, it is possible to house only half the number per acre, and yet have neither a sufficiency of air-space round the buildings nor any sanitary arrangements. The power to enforce the

former is in the hands of the Sanitary Inspector, when the Local Authority has adopted a code of bye-laws worthy of the name.

Other important provisions in bye-law No. 53 relate to sites adjoining two streets meeting at an acute angle, and to the necessity for additional open spaces where part of the building projects in the rear; there is also a provision concerning the re-erection of buildings on the original site.

Before taking up the M.B.L. on the ventilation of the

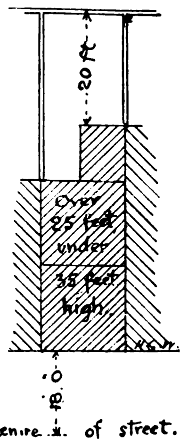


Fig. 99.—House of Three Rooms on Ground Floor, with Bedrooms and Attics above.

inside of a dwelling, it will be desirable to devote a little space to the consideration of the constituents of air, the necessity for an adequate supply, what amount constitutes an adequate supply, and some simple tests for determining the amount of impurity there may be in the atmosphere of a room.

Ventilation is a term applied to the method by which a due supply of fresh air is maintained in buildings, and in other confined places such as mines and ships. The word is derived from the Latin *ventus*, the wind; and was

first used about 200 years ago by a French scientist, who devoted a great deal of time, money, and skill to studying the principles of the science. His method of ventilation consisted in the propulsion of air by means of a fan, and the man who worked the fan was called the "ventilator." This word has since changed its meaning, and is now used to denote a hole through which air passes or is intended to pass.

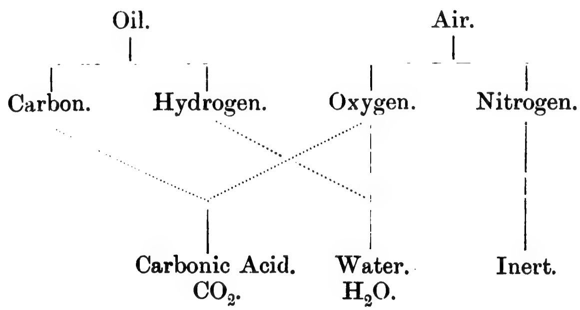
There is considerable confusion in the minds of many persons as to the effect on the body of hot air and foul air, and a word or two on this matter will not be out of place. Everyone knows that covering the face with a cloth will soon produce a feeling of heat, followed by still more distressing symptoms; the same feeling is experienced in an overcrowded room, and the cause is the same in both cases. To the heated atmosphere are attributed the lassitude, discomfort, and lowering of the vitality so familiar to all who frequent overcrowded assemblies; but in a well-ventilated Turkish bath, where the temperature is considerably higher, no such distress is felt, and this shows at once that it is not heat, but something else, that causes the discomfort. That something else is foul air, which lowers the vitality of the body until it becomes painfully sensitive to the slightly raised temperature of the respired air and thus gives warning of the danger. Many of the evils supposed to result from the transition from heated places of public assemblies to the cold night air are due to the enfeebled condition of the body consequent upon the inhalation of a vitiated atmosphere rather than to the mere change of temperature.

COMPOSITION OF AIR.

Oxygen	from	20·87	to	20·96
Nitrogen	,,	79·00	,,	79·00
Carbonic acid	,,	·04	,,	·02
Ozone, salts of sodium, organic matter, ammonia, etc.	,,	·09	,,	·02
		100·00		100·00

Pure air may be said to consist of oxygen, nitrogen, aqueous vapour, carbonic acid, and small quantities of ozone, salts of sodium, organic matter, ammonia, etc. The proportions are varying, but the foregoing table shows the average in parts per 100.

The nitrogen is unvarying in quantity, and inert in its quality. It supports neither life nor combustion, and one of its uses, if not its principal use, seems to be to dilute the oxygen. The oxygen is the effective agent in the air, and is the constituent absolutely necessary for life. The maintenance of the bodily heat, energy, and the various internal complex processes depends on a constant supply of oxygen. Life, to represent the complex by the simple, may be regarded chemically as similar to the burning of a lamp. In the lamp flame the oxygen of the air combines with and converts the carbon and hydrogen of the oil into carbonic acid and water, as indicated by the following diagram :—



In a lamp this operation goes on with such rapidity as to cause heat enough to make the disengaged particles of carbon incandescent, and so we get light. In the human body the process is slower, and the temperature remains at about 98·4° F., but the essence of the process is the same, and the products are also mainly carbonic acid and water. With the exception of ozone, all the other constituents are impurities, and arise in various ways. They are—(*a*) given out by the lungs, the products of respiration consisting chiefly of carbonic acid; (*b*) thrown off from the skin through the pores,

consisting chiefly of organic matter and ammonia; (*c*) the products of combustion, lamps, gases, fires, etc., also chiefly carbonic acid gas; (*d*) effl via from trades; (*e*) effluvia from sewers; (*f*) effluvia from the soil; (*g*) effluvia from unremoved putrefactive or putrefying refuse, etc., all of which are complex in their composition, nauseating in their odour, and dangerous to health.

Ozone is a constituent of which very little is known; it is conjectured to be electrified oxygen, and to be a compound molecule made up of one double and one single atom of oxygen (O_2O). It is, however, only found where the air is very pure (mountains and seashores), and is absent in towns, except immediately after a thunderstorm, when the air has been cleansed and purified.

In dealing with the subject of ventilation so far as it immediately concerns us, the three pollutions first mentioned must claim our attention—carbonic acid from the lungs, organic matter from the pores, and the products of combustion.

It has been shown in the table on p. 114 that the average percentage of carbonic acid in town air of normal purity is about ·04. Now the quantity of air each person requires must be a proportion between the utmost allowable vitiation and the amount of CO_2 discharged into the air, plus the impurity already present. The utmost allowable vitiation must not exceed the least amount that is evident to the keenest sense of smell. This has been found to allow an added percentage of ·02 of CO_2; therefore, air with such added percentage is foul, and with a lower percentage is fresh.

	Fresh Air.		Foul Air.
Oxygen	20·91	average	20·89
Nitrogen	79·00	of	79·00
Carbonic Acid ..	·04	former	·06
Etceteras	·05	figures	·05
	100·00		100·00

The amount of carbonic acid expired is given by Dr. Parkes ("Hygiene," p. 134) as ·6 cub. ft. per hour; but it must be manifest that the occupation of each person

must govern the calculations. Another authority gives the amount for the following persons :—

Child	.. ..	·46	cub. ft.
Woman	.. ..	·62	,, ,,
Man during repose	.. .. ..	·50	,, ,,
,, ,, slight exertion	.. ..	·76	,, ,,
,, ,, ordinary work	.. ..	·92	,, ,,
,, ,, strong exertion	.. ..	1·50	,, ,,

However, ·6 is a convenient figure. Expired air contains the following proportions :—

Oxygen	15·91	
Nitrogen	79·00	
Carbonic Acid ..	4·70	
Etceteras	·39	(chiefly organic matter).
	100·00	

Sufficient air must be introduced, or every person given sufficient space to reduce the carbonic acid by 250 per cent. and to make up the oxygen consumed at each respiration. A person standing in the open air on a calm day is exposed to about 32,000 cub. ft. of air passing by him per hour. It is impossible that he should be supplied with this amount in a closed space, but careful experiments by Dr. Parkes have shown that the best room ventilation which can be reasonably available will supply 3,000 cub. ft. per head per hour. The air will then remain absolutely without sensible odour, and the carbonic acid impurity will not exceed 6 parts in 10,000 (or ·06). This is ideal ventilation.

This experiment is borne out by the following formula of Dr. de Chaumont (Parkes' "Hygiene," p. 135) :—

$$V = \frac{r^1 - R}{r}$$

where V = volume of air required per hour.

R = ratio of CO_2 naturally in air = ·0004 per cub. ft.

r^1 = amount respired per hour = ·6 cub. ft.

and r = ratio to which r^1 should be reduced = ·0002

$$V = \frac{\cdot 6 - \cdot 0004}{\cdot 0002} = \frac{\cdot 5996}{\cdot 0002} = 2{,}998$$ or nearly 3,000 cub. ft. per hour.

Therefore, in a room containing 100 cub. ft., the air should be changed thirty times per hour for each person; or if the room contains 1,000 cub. ft., the air should be changed three times in the hour for each occupant.

It might be asked why so large an amount of air is required, considering the small amount each person actually inspires (15 cub. ft. or 18 cub. ft.). The necessity can best be illustrated by the analogy of a water supply, as given by Professor Jacob, somewhat as follows: "Engineers allow a minimum of 20 gal. a head in estimating the amount of water to be supplied to a town. The water is drawn from a tap, and having been used is discharged into a drain. The fouled water does not again mix with the common supply. But imagine a household of ten persons with the 20 gal. per head in one central cistern, capable of holding 200 gal., from which all water must be taken, and to which the fouled water must be returned. Imagine the abominable state of such cistern after a few hours' use, and it will then be easy to understand that nothing short of a rapid stream of many thousand gallons a head flowing through such cistern would keep the water pure.

"Something of this kind obtains in many village communities in India, but in civilised countries such an arrangement would be considered inexpressibly foul; yet a precisely similar condition of things exists in the air-supply in a confined space. The air each person breathes is taken from a common stock, and returned with all its gaseous impurities, laden with moisture and heat, into the same common stock, which naturally enough quickly becomes foul. To keep the air pure these impurities must be removed as rapidly as they are exhaled. The prodigious amount of air the living body requires is not for the purpose of supplying it with oxygen, but in order so to dilute the poisonous substances produced by respiration that they become innocuous and free from odour."

The products of combustion from fires generally pass out into the atmosphere at once by means of the chimney; those of lighting are for the most part allowed to diffuse in the room. Coal gas when fairly purified consists of the following parts per 100 (Parkes' "Hygiene," p. 101):—

COMPOSITION OF COAL GAS.

Hydrogen	40·	to	45·58
Marsh gas (carburetted hydrogen)	35·	,,	40·
Carbonic oxide	3·	,,	6·60
Olefiant gas (ethylene)	3·	,,	4·
Acetylene	2·	,,	3·
Sulphuretted hydrogen	0·29	,,	1·
Nitrogen	2·	,,	2·50
Carbonic acid	3·	,,	3·75
Etceteras	·5	,,	1·
	88·79	,,	107·43

When the gas is burnt, the results are as follows :—

Hydrogen	0·	
Nitrogen	67·	
Water	16·	
Carbonic acid	7·	
Carbonic oxide	6·	With perfect combustion, practically 0 00.
Etceteras	4·	
	100·00	

A cubic foot of gas when burnt up will unite with 1·60 cub. ft. of oxygen, and produce 2 cub. ft. of carbonic acid, and f om ·3 to ·5 gr. of sulphurous acid. In other words, 1 cub. ft. of gas will destroy the entire oxygen of about 8 cub. ft. of air. An ordinary oil lamp, burning about 154 gr. per hour, consumes the oxygen of about 3·2 cub. ft. of air, and produces a little more than half a cubic foot of CO_2. Thus a lamp is only about one-fourth as harmful as a gas burner burning only 1 cub. ft. per hour ; but most burners consume at least 3 cub. ft. per hour, thus producing 6 cub. ft. per hour of carbonic acid Calculating as before, with the formula—

$$V = \frac{r^1 - R}{r}$$

where r^1 = amount of CO_2 per burner—

$$V = \frac{6 - \cdot0004}{\cdot0002} = \frac{5\cdot9996}{\cdot0002} = 29{,}998, \text{ or } 30{,}000 \text{ cub. ft.}$$

From this may be seen what a large supply of air is necessary in a room where gas burns continually. Not all rooms are occupied during the whole twenty-four hours, nor is the gas burning continually; so that although the calculations are theoretical, and such ventilation is ideal, yet in practice 2,000 cub. ft. per head, and 6,000 cub. ft. per burner, is allowable, except where the nature of the work indicates that the body of each worker gives off 1 cub. ft. or more of CO_2 per hour. However, windows, doors, and other air passages should be opened wide as soon as the room is unoccupied, and the whole air of the room changed.

CARBONIC ACID IN AIR.

	Contents—cubic centimetres	*Cubic in.*		*If turbid, volumes of CO_2.*		
				In 10,000.	*Per cent.*	
Centimetre = ·3937 in. Cubic centimetre = ·061 cub. in.	450	27·45	Add 15 c.c. of transparent lime-water = ·915 cub. in.	6 or	06	utmost allowable.
	350	21·35		7 ,,	·07	
	300	18·30		8 ,,	·08	
	250	15·25		10 ,,	·10	
	200	12·20		12 ,,	·12	
	100	6·10		16 ,,	·16	produces headache.

The following is one method of testing and roughly ascertaining the amount of carbonic acid in the air of a room, and is given by the late Professor Jacob in his "Notes on Ventilation and Warming," p. 13: "Six stoppered bottles are taken, containing respectively 450, 350, 300, 250, 200, and 100 cub. centimetres. These are filled, by means of a small hand-ball syringe, with the air of the room to be tested. A glass tube or pipette, holding exactly 15 cub. cm., is then filled with clear, transparent lime-water and emptied into the smallest bottle, which is then shaken. If the fluid becomes turbid, the amount of carbonic acid will be at least 16 parts in 10,000. If no turbidity occurs, repeat the opera-

tion with the next largest bottle. Turbidity will here indicate 12 parts. In similar fashion, turbidity in the 250 c.c. bottle indicates 10 parts CO_2; in the 300 c.c. bottle, 8 parts; in the 350 c.c. bottle, 7 parts; and in the 450 c.c. bottle, less than 6 parts. To judge of the turbidity, mark a piece of paper with a lead-pencil, and gum it to the bottle with the marked side next the glass. If there be turbidity, the mark will be invisible. The foregoing shows these figures in tabular form.

§ 157 of the P.H.A., 1875, which is still being dealt with, allows Local Authorities to make bye-laws "with respect to the ventilation of buildings"; and the L.G.B. has drawn up M.B.L. on the subject. It must be confessed that they deal very tenderly with it, not requiring anything very extravagant or complicated, and trusting a good deal to the crevices of windows and doors, and the flues of fire-places.

The first M.B.L. on the subject reads as follows:—

M.B.L. No. 54: "Every person who shall erect a new domestic building shall construct in the wall of each storey of such building which shall immediately front or abut on such open spaces as, in pursuance of the bye-laws in that behalf, shall be provided in connection with such building, a sufficient number of suitable windows, in such a manner and in such a position that each of such windows shall afford effectual means of ventilation by direct communication with the external air."

The two preceding clauses (M.B.L. No. 52 and No. 53) provided for a minimum amount of open space to be left in the front and at the rear of every new domestic building. No. 54 provides that the windows shall overlook these open spaces, so as to secure reasonable means for ventilation. A later bye-law provides for the size of the windows and the area of the portion that must be made to open. The ventilation of the space below the floor is dealt with in M.B.L. No. 55, which has already been quoted (see p. 31).

Wherever the lowest storey of a house has a boarded floor, it is absolutely necessary to provide ample means of ventilation to the space below the floor; for, unless a current of air can pass constantly and freely between the wood joists and the surface of the concrete or asphalt that is laid over the surface of the ground beneath the house in

accordance with M.B.L. No. 11 (see p. 20), it is almost certain that dry-rot will attack the woodwork, and the floor will fall to pieces in a comparatively short time.

It has already been mentioned that some towns have not adopted M.B.L. No. 11, and others have added "where the dampness of the ground renders it necessary"; as though the "concrete bed" were to protect against subsoil water only, and not against ground air also! In these unfortunate towns there ought to be at least 9 in. between the underside of the joists and the surface of the ground.

Fig. 13 (see p. 31) shows a space of 18 in., ventilated by large air-grids, and a flue running up alongside the fire-place of the room above, and acting as an exhaust shaft. Little is yet known as to dry-rot; it is certain, however, that closed-in spaces under floors are generally attacked, more especially when ground air finds admittance. It is surmised that the spores or seeds of dry rot floating in the air are breathed into the lungs, and tend possibly to induce the growth of dangerous bacteria, bacilli, and micrococci in the system.

The next M.B.L. returns to the windows of rooms, and reads thus:—

M.B.L. No. 56: "Every person who shall erect a new building shall construct in every habitable room of such building one window, at the least, opening directly into the external air, and he shall cause the total area of such window, or, if there be more than one, of the several windows, clear of the sash-frames, to be equal at the least to one-tenth of the floor area of such room. Such person shall also construct every such window so that one-half, at the least, may be opened, and so that the opening may extend in every case to the top of the window."

The necessity for a window being of ample size is well understood. It has been proved that sunlight, or at least broad daylight, is necessary to maintain health, and, in measuring, the glass area should be taken. It will be observed that the window must open "directly into the external air," and that a window opening into the interior of a building (a "borrowed" light) will not be in accordance with the regulation. No particular position for the window is mentioned; but it should be arranged so that the top of the

window is near the ceiling. Neither is any particular shape of window required, but it must be constructed so that one half at least may be opened, and the opening must extend to the top of the window; provided these conditions are observed, the window may be a sash-window double-hung, a French casement, a Yorkshire light (one half sliding horizontally in front of the other half), or a sash-window hung on pivots or hinges. It has been found by experiment that an ordinary window is so constructed as to admit through its crevices and chinks 8 cub. ft. of air per minute, even when closed.

An alternative clause (No. 56A), prescribing the details of the ventilating arrangements, is also given, to enable the Local Authority to deal more satisfactorily with the subject in those cases where M.B.L. No. 56 is deemed to be inadequate.

The ventilation of staircases is dealt with in a supplementary clause which reads as follows:—

No. 56B: "Every person who shall erect a new building constructed or intended or adapted to be occupied by more than two families in separate tenements shall cause the principal staircase to be used by the several families in common to be adequately ventilated upon every storey above the ground storey, such ventilation to be provided except where such staircase is open to the external air by means of windows or skylights opening directly into the external air, and he shall cause the total area of such windows or skylights upon every storey clear of the sash frames to be equal at the least to one-eighth of the area on plan of such principal staircase. He shall cause such staircase to be provided with a sufficient handrail properly and securely fixed."

The next M.B.L. relates to the ventilation of rooms without fireplaces:—

M.B.L. No. 57: "Every person who shall erect a new domestic building shall cause every habitable room of such building which is without a fireplace, and a flue properly constructed and properly connected with such fireplace, to be provided with special and adequate means of ventilation by a sufficient aperture or air shaft which shall provide an unobstructed sectional area of 100 sq. in. at the least."

This provision for an aperture of 100 sq. in. is without reference to the size of the room. It will presently be shown

by calculation that this air opening should be 1 sq. in. in area for each 60 cub. ft. of space in the room, and some towns have inserted this figure in their bye-laws, with the approval of the L.G.B. It will also be shown what quantity of air is drawn out of a room by a chimney. It is apparent, however, that a little room, 8 ft. by 8 ft. by 8 ft., over a scullery, with one occupant, would have excessive ventilation through a 10-in. by 10-in. ventilator; whilst in a large attic, with three or four servants sleeping in it, the stipulated outlet might be ridiculously small. In Fig. 100 is a sketch of a ventilator adequate for the purpose. An opening into a flue may be provided, but it must be observed that the area of the opening is to be 100 in., and that an ordinary grating 10 in. by 10 in. will not suffice, as the bars will obstruct nearly one-half of the opening.

The next M.B.L. refers to public buildings only.

M.B.L. No. 58: "Every person who shall erect a new public building shall cause such building to be provided with adequate means of ventilation."

There is not the slightest indication as to the intent and meaning of the word "adequate"; but the question of ventilating public buildings is so very wide, and depends upon so many varied conditions, that it is perhaps impossible to draw up a bye-law in any other terms.

Figures have already been given (see p. 117) to show that each person requires 3,000 cub. ft. of air per hour; but that was ideal ventilation. The sanitary inspector may aim at this, but much of his work lies at the antipodes of the ideal. A little guidance is obtained from other publications of the L.G.B. On looking at their requirements for common lodging-houses, it will be found that the secretary of the Board, in 1877, wrote: "In rooms of ordinary construction to be used for sleeping, where there are the usual means of ventilation by windows and chimneys, about 300 cub. ft. will be a proper standard of space to secure to each person; but in many rooms it will be right to appoint a larger space, and this can only be determined on inspection of the particular room."

In the Factory and Workshop Act, 1901, it was enacted that in a factory there should be at least 250 cub. ft. for each person in the daytime, and 400 cub. ft. at night. Persons

awake can regulate their air-supply when the air feels stuffy, but persons asleep are unable to do so; therefore 300 cub. ft. may be considered as the irreducible minimum of air-space for sleeping-rooms.

A practice in force in Glasgow, which is worthy of being adopted throughout the country, may be mentioned here. In those quarters of the city where overcrowding is likely to occur, a ticket is placed on the door stating the ascertained cubic contents, and stating also the maximum number of occupants that should be allowed to sleep in the room. The police officer or sanitary inspector is thus able to detect

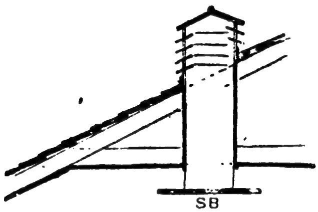


Fig. 100.—Ventilator through Ceiling and Roof.

overcrowding, and the tenant of the house or room is unable to plead ignorance of the law when found to be exceeding the limit.

While it is by no means difficult to prove that the fundamental principles of the science of ventilation are precise and simple, yet the various methods of applying these principles, and of securing a constant supply of fresh air, are legion. The ventilation expert is apt to declare that there is only one sure and certain method of ventilation, namely, his own, that all others are failures in practice, and that the systems recommended by other specialists are sure to be inefficient and useless.

Before dealing with the various methods of securing ventilation, the following three points must be mentioned, but there is no need to consider the reasons which govern them, or the experiments which determined them.

(1) *Temperature.*—In ventilating a room, the openings should be sufficiently large to provide for summer ventilation; and not so large as to make it impossible to keep the room

warm during winter. To be comfortable, the temperature should not be lower than 48°, and not higher than 60° F., the mean being 57° F. This will, of course, vary with occupations, constitutions, external temperature, and the direction and force of the wind.

(2) *Speed of Incoming Air.*—The speed at which air may travel without being felt as a draught is 5 ft. per second. Any openings provided for incoming air must be sufficiently large for the whole supply to enter at a rate of 5 ft. per second or less.

(3) *Times of Change per Hour.*—The organic matter discharged from the skin and the lungs was mentioned among the impurities. The amount has never been precisely determined, nor is it possible to estimate it correctly. It is this which imparts to badly ventilated rooms the close, stuffy, fœtid odour, thus differing from the CO_2, which is inodorous. This organic matter diffuses slowly, and specialists in ventilation agree that the whole of the air in a room should be entirely changed three times in the course of an hour. Even in winter, when the external air is below freezing point, it should be changed three times every two hours.

The ideal current of moving air would be one that is symmetrical in its sectional area with one superficies of the apartment, passing gently and equably through the cubical space until it quits the room at the opposite superficies; and, although such an ideal is unattainable, the attempt should be made to reach as close an approximation thereto as possible. It is proposed now to discuss the leading systems, their principles, advantages, and disadvantages, without reference to the inlets, outlets, cowls, etc., of different patentees.

There is, first, what is called the natural system, where an opening at the top of the room lets out the foul air, and an opening lower down admits the fresh air (see Fig. 101). There is, second, what is called mechanical or forced ventilation, on the plenum or exhaust system. And there is artificial ventilation of various sorts: inlet openings at the top, outlet at the bottom of the room, or both at the top, etc.

Natural ventilation consists in providing an opening in or near the ceiling for the outlet of foul air, and an opening

at a lower level for the inlet of fresh air. The efficiency of this plan is proved scientifically, and is based upon the fact that heat expands and cold contracts. To this natural law air is no exception. Foul air is generally warmed to some extent, and then rises to and passes out by the opening at the higher level, its place being taken by cooler air entering at the lower of the two openings. Let it be noted here that, in order to ventilate, there must be two openings at the least, one to act as an inlet, the other as an outlet. The effectiveness of this natural ventilation depends entirely on the difference of temperature between the external air and the internal air, and it will at once be apparent that this system may be very effective in winter, and fail absolutely in summer.

Air dilates or expands $\frac{1}{491}$ of its volume for each degree of Fahrenheit that its temperature is raised (Parkes, p. 145). Consequently, its weight is reduced in the same proportion, and the lighter air is thus forced to the upper part of the room by the greater weight of the cooler air—just in the same way that a bladder of air, submerged in a pond, will be forced to the top by the greater weight of the surrounding water, immediately the restraining force is removed. If an opening is made in the upper part of a room, the warmer or lighter air passes through, forced through by cooler and heavier air coming into the room through openings at a lower level. As the fresh air is in its turn heated, the movement is kept up in a constant stream, cold air entering by one set of orifices, and hot air escaping by another.

It has already been said that ventilation is an exact science, and that its results are arrived at by calculation. It will be well to examine the method of arriving at the quantity of air which passes through an outlet shaft. Parkes writes: "The mode most generally used is based on two well-known laws—first, that the velocity in feet per second of falling bodies is equal to (nearly) eight times the square root of the height through which they have fallen; and, secondly, that fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the partition."

This is frequently called the rule of Montgolfier. The

formula is $V = \sqrt{2\,g\,H}$; g being the acceleration of velocity in each second of time, namely, 32·18 ft., and H the height of the descent. (See Fig. 101.)

"The pressure of air upon any surface," he continues, "may be represented by the weight of a column of air of uniform density of a certain height. Thus the pressure of the atmosphere at the surface of the earth is about 14 lb. on the square inch, and this would be the weight of a column of air of about five miles high. Air, therefore, rushes into a vacuum with a velocity equal to that which a heavy body would acquire in falling from a height of five miles—namely, 1,339 ft. per second. But if, instead of rushing into a vacuum, it rushes into a chamber in which the air has less pressure than outside, its velocity will be that due to a height which represents the difference of pressure of outside and inside. . . .

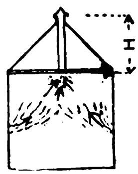


Fig. 101.—Natural System of Ventilation.

"Air is dilated 1 part in 491 of its volume for every degree Fahrenheit that its temperature is raised; consequently the difference of pressure outside and inside will be as follows: The height from the aperture at which the air enters to that from which it escapes, multiplied by the difference of temperature between outside and inside, and divided by 491. If the height be 20 ft., and the difference of temperature 15°, we have the height to produce velocity of inflowing current (or H) $= \frac{20 \times 15}{491} = 0{\cdot}61$ ft. : and $V = 8\sqrt{\cdot 61} = 8 \times \cdot 781 = 6{\cdot}248$.

"This, however, is the theoretical velocity In practice an allowance must be made for friction of one quarter, one-third, or even one-half, according to circumstances. The diminution of velocity from friction is in proportion to the

length of the tube, and is inversely as the diameter. Right angles greatly increase the friction. The friction also increases as the square of the velocity. The deduction of one-quarter would leave 4·686 lin. ft. per second as the actual velocity. If this be multiplied by the area of the opening in feet, . . . the amount of air is expressed in cubic feet per second, and multiplied by 60 will give the amount per minute. . . As the action increases with the difference in temperature, it is most powerful in winter, when rooms are artificially warmed, and is least so, or is quite arrested in summer, . . . when the internal and external temperatures are identical." ("Hygiene," p. 146.)

In providing inlet and outlet openings while taking care not to make them too small, it should also be remembered that a small chink round each door and round each window will amount to an appreciable area—at least, in most of our houses—and that when the fire is lit the chimney flue carries away from 200 cub. ft. to 1,000 cub. ft. per minute. The following calculation will serve to show the reason why six people in a room, with the gases lit, do not suffocate :—

6 persons @ 2,000 cub. ft. each per hour	=	12,000
3 gaslights @ 6,000 ,, ,,	=	18,000
		30,000
Fireplace 60 minutes at 500 cub. ft.	=	30,000

The room certainly gets very warm, but generally because the inlets are inadequate. As a rule, it is found that if an inlet has been provided, it has been blocked because of a draught. The real cure of the draught would have been to make the inlet larger. A draught was felt because the inlet was contracted, and the air had to pass in at a quicker rate than 5 ft. per second. It is a good plan to provide several inlets, or there is a danger of the incoming air taking the shortest cut to the outlet and leaving the general body of the air in the room stagnant (see Fig. 102). This has been proved to be the case on several occasions.

It has been found by experiment that the best level for inlet openings is about 5 ft. or 6 ft. from the floor. They may be provided in many ways—(*a*) an opening hidden by

the architrave of the door, as in Fig. 103; (*b*) a number of holes bored in the meeting bars of the window, as in Fig. 104; (*c*) a strip of wood placed on the window sill, and the window

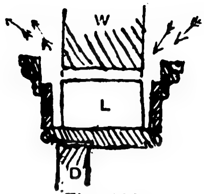


Fig. 103.

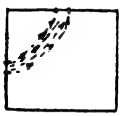


Fig. 102.

Fig 104.

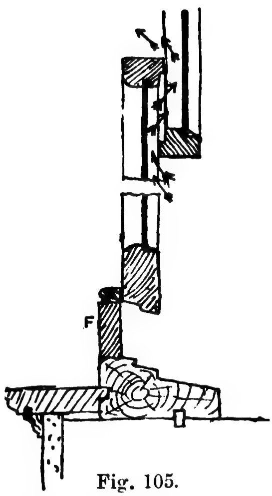


Fig. 105.

Fig. 102.—Air Current Direct from Inlet to Outlet. Fig. 103.—Air Inlet over Lintel of Door. Fig. 104.—Air Holes Pierced through Window Bars. Fig. 105.—Air Inlet at Window Bars.

shut down upon it, leaving an opening between the meeting bars, as in Fig. 105; (*d*) a series of Tobin tubes in different corners of the room, and connected to the fresh air (see Fig. 106); (*e*) a series of Sheringham valve inlets (see Fig.

107). For domestic purposes it will generally be found that the chimney forms an ample outlet If another outlet is required, a grating in the centre of the ceiling, connected with a tube running between the joists and taken into the open air, as in Fig. 108, will be found to meet the case. A

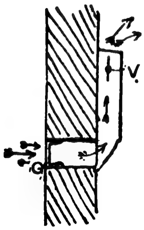


Fig 106.—Tobin Tube Inlet.

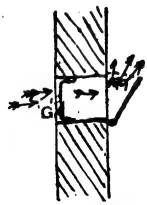


Fig. 107.—Sheringham Inlet.

mica flap, or other provision, to prevent down-draught when the wind blows directly against that wall, will be necessary. As already stated, this form of ventilation, the natural, is only effective in the winter season, when there is a marked difference between the internal and the external temperature.

The forced or mechanical ventilation is of two kinds, one

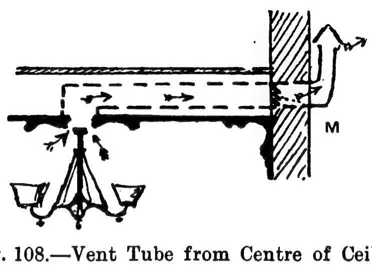


Fig. 108.—Vent Tube from Centre of Ceiling.

being the plenum and the other the vacuum or exhaust principle. Mechanical means of some sort are resorted to in order to keep the air in motion, either fans (see Fig. 109) or blowers, or fires, or a combination of these. In plenum ventilation the propulsive force is applied to the incoming

air and the apartment filled—hence the name, which is a Latin word meaning full. Outlets are provided at convenient places, and the foul air is driven out by the air forced in.

"The advantages of this method are its certainty and the ease with which the amount thrown in can be altered. The stream of air can be taken from any point, and can, if necessary, be washed by passing through a thin film of water, or filtered through a thin screen of moistened cotton, and can be warmed or cooled at pleasure. The disadvantages are the cost, the danger of the engine breaking down, and some difficulties in distribution. If the air enters through small openings at high velocity, it will make its way to the

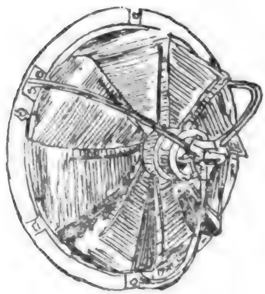


Fig. 109.—Blackman Air Propeller.

outlets without mixing. The method requires, therefore, great attention in detail." (Parkes' "Hygiene," pp. 161–2.)

The exhaust, or extraction, or vacuum principle is the converse of the plenum. The propulsive force is applied to the outgoing air. This may be done in several ways. Thus a fan may be used; but in such case there are the disadvantages of expense and of probable breakdown of the engine. A steam jet may be used; this also is expensive, and unless great care is taken it is noisy. A fire at the foot of a tower may be adopted, but here again the cost of maintaining the fire has to be met, as well as other disadvantages. (*a*) There is the inequality of the draught, as it is almost impossible to keep the fire at a constant height (Parkes, p. 159); (*b*) the inequality of movement from different

rooms—the nearer ones will have the air changed several times in an hour, those at a distance may hardly feel the influence; (*c*) if the shaft is large, there may be no movement in the air of the rooms, but a down and up current circulating in the shaft itself (see Fig. 110); (*d*) the possibility of reflux of smoke from the shaft to the rooms; (*e*) "the impossibility of properly controlling the places where fresh air enters—it will flow in from all sides, and possibly from places where it is impure, as from water-closets, etc. Air is so mobile that, with every care, it is difficult to bring it under complete control—it will always press in and out at the point of least resistance" (Parkes, p. 159). For these reasons it will be seen that the plenum system is more likely to be a success than the exhaust system in all cases where natural ventilation is found to be inadequate.

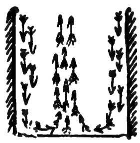


Fig. 110.—Down and Up Currents in Large Shafts.

Artificial ventilation covers those systems where both outlet and inlet are at the top and close together; or where the outlet is at floor level, and other eccentricities of the same sort. It has been proposed to put the two openings side by side (Fig. 111), or the one round the other (Fig. 112). The great objection in these cases is that the incoming air must to some extent cool the foul air, and either cause it to fall back into the apartment or to pass out much more slowly than would otherwise be the case. The reason advanced for putting the outlet at the floor level is that carbonic acid gas, being heavier than common air, will sink to the ground. This is theoretically true; CO_2 in bulk is heavier than air when both are at the same temperature. But in dealing with room ventilation it will be found that the CO_2 is mixed with the air of the room, that it is given off from the body at nearly 97°, and from the gas flame at a very much higher

temperature. Hence the CO_2 rises to the ceiling, and to cool it there by a current of fresh cold air and send it down

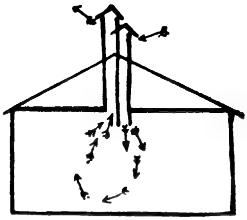


Fig. 111.—Top Ventilation with Two Tubes.

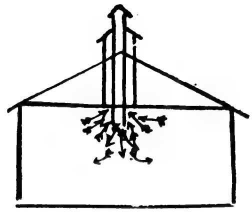


Fig. 112.—Top Ventilation with Concentric Tubes.

to the floor for extraction is to re-contaminate the atmosphere of the room.

The following method of testing and ascertaining roughly the amount of carbonic acid (CO_2) in the air of a room is given by the late Professor Jacob in his "Notes on Ventilation and Warming":—"Six stoppered bottles are taken, containing respectively 450, 350, 300, 250, 200, and 100 cubic centimetres. These are filled, by means of a small hand-ball syringe, with the air of the room which has to be tested. A glass tube or pipette, holding exactly 15 cubic centimetres, is then filled with clear transparent lime water, and emptied into the smallest bottle, which is then shaken. If the fluid becomes turbid, the amount of carbonic acid will be at least 16 parts in 10,000. If no turbidity occurs, repeat the operation with the next largest bottle. Turbidity will here indicate 12 parts. In similar fashion, turbidity in the 250-c.c. bottle indicates 10 parts CO_2; in the 300-c.c. bottle, 8 parts; in the 350-c.c. bottle, 7 parts; and in the 450-c.c. bottle, less than 6 parts. To judge of the turbidity, mark a piece of paper with a lead pencil, and gum it on to the bottle with the pencil mark inside. If there be turbidity, the mark will be invisible." Fifteen cubic centimetres = ·915 cub. in., and 100 c.c. = 6·10 cub. in.

Other impurities in the atmosphere are carbonic oxide—a product of imperfect combustion in coke stoves; sulphuretted hydrogen and sulphurous or sulphuric acid gas, from the burning of badly purified coal gas, etc. Sulphuretted hydrogen may be recognised by the blackening of silver

plate, by the leather bindings of books falling to pieces, etc. The testing of the air for these impurities is a more complicated process, and the better plan is to fill a large glass bottle (to hold about a gallon) with the air of the room, and submit to a chemist.

To ascertain the direction of the air currents in a room, long filaments of the finest silk, from 6 in. to 12 in. in length, should be attached to the ceiling at different points; thin rods reaching from floor to ceiling should be erected at different parts of the room, and similar rods placed horizontally at different levels; to these rods the filaments should likewise be attached. The directions assumed by these filaments will indicate both the direction and the force of the moving currents. Smoke has also been used, but the results are somewhat fallacious, as the smoke, when warm, rises and moves independently of the general air currents. If a smoke test is desired, the best apparatus consists of a sponge filled with muriatic acid suspended over a small basin of ammonia. In this case the fumes have no heat. For ascertaining the direction of the air currents in a large chamber, Mr. Sugg made use of small air balloons.—H. G. WHYATT.

Some of the above tests are open to certain objections: For example, to test by chemical analysis is both a tedious and a costly process, and Professor Jacob's method requires much practice and patience, and a multiplicity of utensils. More convenient for general use, probably, is Dr. Scurfield's ventilation indicator, which shows quickly and accurately the amount of carbonic acid in any sample of air that is tested. It is made by J. Defries & Son, Ltd. The usual plan is to obtain first a standard of purity by testing a sample of what may be considered normally pure air, the test being made out of doors at a distance from any building. Afterwards the air of any number of rooms may be tested, and the result compared with the standard. When ready for use, the apparatus consists of an aspirator filled with water and supplied with a gauge, surrounded by a number of tubes, each of which can in turn be connected with the aspirator. These tubes all contain exactly the same quantity of baryta and phenolphthaleine, a pink solution which is deprived of its colour when brought into contact with carbonic acid. The air to be tested is passed through this solution, which

loses its colour quickly or slowly, according to the amount of carbonic acid in the air. The quantity of air that has been tested is shown by the amount of water—recorded on a gauge—that has run off from the aspirator; so that, in testing two samples of air, if to decolorise the first tube 1·8 cans of air (represented by so much water) are required (sample 1), and to decolorise the second tube 1·2 cans are required (sample 2), the amount of carbonic acid in sample 1 is to sample 2 as 1·8 is to 1·2; in other words, sample 2 contains half as much again of carbonic acid as sample 1. To take another example: if for the standard test the gauge shows 9, and the first room tested shows 4·5, the air in the room contains twice as much carbonic acid as the outside air.

The manner of using Dr. Scurfield's apparatus is as follows: Having filled the aspirator with water, and the tubes with the pink solution, the aspirator is connected with one of the tubes, the cock at the bottom of the gauge is opened, and air bubbles through the tube and into the aspirator, the water flowing through the gauge into the can below. Opinions differ as to the excess of carbonic acid allowable in the air of a room; it should not be more than twice the amount contained in normally pure air; should the apparatus register more than this, the ventilation is defective. Forty minims of the baryta solution and 60 minims of the phenolphthaleine solution added to 1 pt. of distilled water make a solution of sufficiently deep colour. The cost of the drugs is not excessive, and the decolorised solution can, by adding a small quantity of baryta, be used over again many times.

CHAPTER IX.

A TYPICAL DWELLING.

IN this chapter it is proposed to describe a type of house suitable for a working man who, being of a thrifty disposition, is systematically saving part of his earnings with the object of buying or building a house for himself.

Choice of Site.—The rich man builds where he will, the poor man where he can. In the neighbourhood of towns the sites available are very limited both in number and in position; very often in a street only one plot of land is unoccupied. Before deciding upon this plot, careful inquiries should be made with the object of ascertaining why it has been left so long vacant; it may be found that a sewer runs under the land, and the local authority refuse their consent to its being built over; or that a neighbour has acquired rights of light; or that the subsoil is unfit to build upon; or that it is an old pit filled with foul refuse. If no defect can be found, and if the soil is clean and dry, if the land is large enough to provide the air-space required by the building regulations or bye-laws, and if the price is reasonable, then the working man may proceed with the purchase of the land. In the country there is a larger choice and the land is cheaper; so that it is possible to secure a far greater area of land at a less price than would have to be paid for a small plot in a town. It is a question to be decided by each man for himself whether fresh air and a piece of garden ground are worth more than the cost of travelling and the time occupied in travelling; or whether proximity to work overbalances the extra cost of living and the absence of country air. The site of the house, wherever it is situated, should be clean and dry; sand or gravel form the best subsoil, clay is inferior. In some districts a bed of concrete covering the whole site of the house is insisted upon by the local authorities; in others it has to be constructed only when the nature of the site requires it. If the ground has been tipped with foul material,

it is illegal to build upon it, by the Public Health Acts Amendment Act, 1890, until the foul matter has been removed or rendered innocuous. If the site has been tipped with clean material, it is desirable to cover it with concrete in any case. The question of soils and sites is discussed in Chapter II.

Aspect.—The aspect of the living-rooms of a house affects the health of the occupants very greatly. It is now a trite saying that "the doctor comes to those places which the sun does not visit"; and it is an established fact that many of the microbes which are the cause of disease are killed by sunlight. Hence, where possible, houses should be so arranged that the sun may shine into all the rooms during some portion of the day; and the rooms should be so planned as to obtain the greatest proportion of sunshine during the times they are

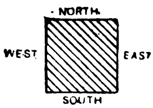


Fig. 113.—House Planned Parallel with the Compass Points.

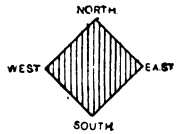


Fig. 114.—House Planned Diagonal with the Compass Points.

occupied. In the case of villas standing in their own grounds it is an easy matter to place the morning-room so as to obtain the morning sun, that is, on the easterly side of the house; and the dining-room, which is most used during the evening, so as to catch the western sun. But in the case of working men's dwellings it becomes more difficult; still, it is not impossible.

It will be seen, from Fig. 113, that if a house is planned with its external walls towards the cardinal points of the compass, the north side will never receive the direct rays of the sun; whilst if the house is set diagonally, as in Fig. 114, the sun will shine into every room during some portion of the day. In the country, where land is cheap, it will be possible for even a working man's house to be thus arranged, and the blessings of sunlight will not be prohibited. In the town, where houses are built in rows, if the streets are laid out north and south the sun will shine into the windows on the east

side in the morning, and on the west side in the evenings; and to ensure the best result the living-room should be arranged on the west side of the row. The plans of the houses will thus vary on each side of the street; on the east side of the street the living-room will be placed at the front, and on the west side of the street at the back; and by this arrangement the evening

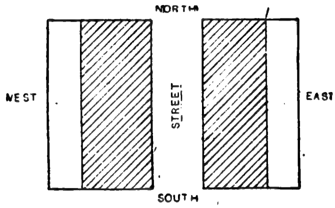


Fig. 115.—Street Planned North and South.

sun will shine into the living-room when the greater part of the family are at home (see Fig. 115). If the streets are laid out in the opposite direction, that is, east and west, the same result obtains as was pointed out in Fig. 113; the north side of each row never receives the sunshine, and will be damp, moss-grown and unhealthy (see Fig. 116). In

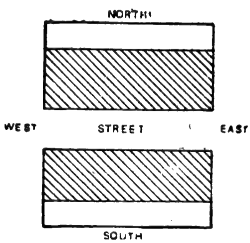


Fig. 116.—Street Planned East and West.

laying out an estate for dwellings, whether for the working or for the higher classes, east and west streets should be avoided; if unfortunately this is impossible, the living-room should always be placed towards the south.

Accommodation.—A few words as to the minimum accommodation that should be provided in a working man's house

before considering typical plans. It will be admitted that most houses have an additional room beyond those apparently provided, namely, room for improvement; and whilst specialists try on the one hand to design cheap houses, on the other hand they are trying to introduce improvements and conveniences into the houses of the working man which

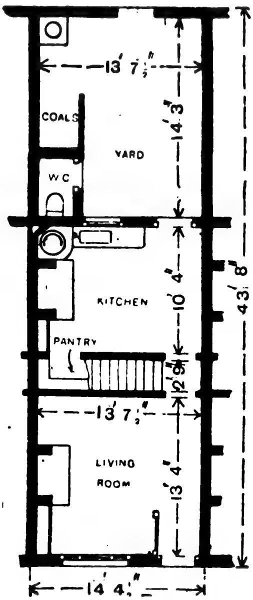


Fig. 117.—Ground Plan of 14-ft. 4½-in. House.

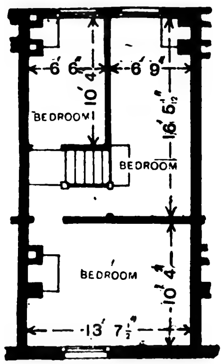


Fig 118.—First Floor Plan of Fig. 117.

a few years ago were supposed to be entirely out of his reach, and by these and other means to increase everywhere the amenities of life.

In a small house, the most important object to be attained is a good-sized living-room; one large enough to contain the whole family without crowding after the labours of the day. There should be a small pantry to allow for the storage of food in such a position that the food may not be contaminated by foul odours or other matters. Where possible a

wash-house or wash-cellar should be constructed so as to keep the steam and smell out of the house. There should be three bedrooms, and this is an easier matter than may be thought possible, as will be seen from the accompanying Figs. 118 and 120. The advantages of three rooms rather than two are many. When a family is growing up, there

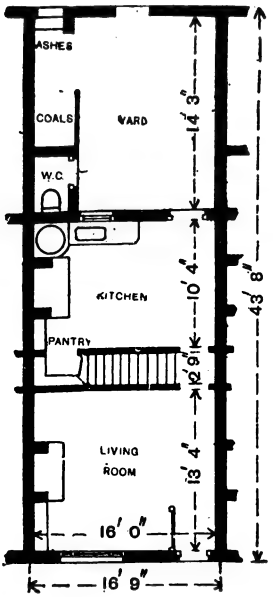


Fig. 119.—Ground Plan of 16-ft. 9-in. House.

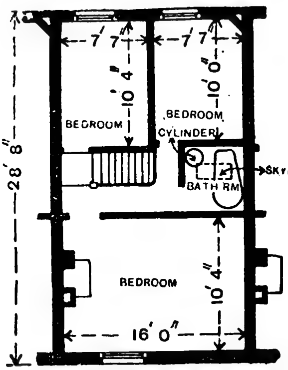


Fig. 120.—First Floor Plan of Fig. 119.

comes a time when the two sexes should sleep in separate rooms; or an occasion may arrive when a visitor has to be entertained, or a fever case isolated, and with three rooms these are easily arranged. No more space is required for three rooms than two; the only difference is the space occupied by the wall; and the additional cost is only the cost of a studded wall, and an additional fireplace or ventilator. The only case where a working man should build himself a house with only two bedrooms is that of an old couple whose

family have gone to live in homes of their own, for it is remarkable that when a working man builds a house for himself (or buys one) he never removes, however large his family becomes. Where possible a bathroom should be arranged, though this is not held to be necessary where public baths are within a reasonable distance.

Plan.—The accompanying Figs. 117 and 118 show the ground and chamber plans of a house designed by a Manchester architect, and erected at Patricroft in 1896 for £153. In this plan the living-room has an area of over 170 sup. ft., or if an inner door is provided and the porch deducted, the area is over 160 ft. The yard has to be 150 ft. in area, but is actually over 190 ft., owing to the provision in the byelaws as to the distance from the back wall of the house being regulated by the height of the building. By a compact arrangement of stairs no space is lost, and three bedrooms are easily secured. The area occupied (including half width of street and passage) is 105 sup. yd.

The plans of another cottage designed by the same architect are illustrated in Figs. 119 and 120. The ground plan (Fig. 119) is much the same as that of the previous cottage (Fig. 117), but is 2 ft. 4½ in. wider. This makes the living-room and kitchen more spacious, but the chief advantage is perceived on the upper storey, where (see Fig. 120) a bathroom has been arranged, in addition to three bedrooms. The area occupied (including the half width of a 12-yd. street, and a 9-ft. back passage) is 123 sup. yd., and the cost (in 1898) was £168 per house.

Area of Site.—This should be as large as possible, and is entirely governed by the cost of the land. It may be taken as a standard basis that a working man should not pay more than 1s. per week for ground rent (unless he makes gardening a hobby, in which case a larger sum is allowable). This equals 52s. per annum. Thus if land can be obtained at 1d. per yd. per annum, he may acquire a site of 624 sup. yd., whilst if the ground rent is 8d. per yd. per annum, the site must not be larger than 78 sup. yd., including the land thrown into front street and back passage. In districts where ground rents are not customary, and where land is purchased out-and-out, it means that, reckoned at 3 per cent., the site must not cost more than £86 13s. 4d.; at 4 per cent., not more

than £65; and at 5 per cent., not more than £52. These and the intermediate areas are shown in the accompanying tabular form.

Area in sq. yards.	Ground Rent per Yard.	At 3 per Cent. Total Cost, £86 13s. 4d. Cost per Yard.		At 4 per Cent. Total Cost, £65. Cost per Yard.		At 5 per Cent. Total Cost, £52. Cost per Yard.	
		s.	d.	s.	d.	s.	d.
78	8d.	22	2	16	8	13	4
89	7d.	19	5	14	7	11	8
104	6d.	16	8	12	6	10	0
125	5d.	13	10	10	5	8	4
156	4d.	11	1	8	4	6	8
208	3d.	8	4	6	3	5	0
312	2d.	5	6	4	2	3	4
624	1d.	2	9	2	1	1	8

These areas include the half width of street and passage, and it will consequently be seen how small the actual area covered by the house will be in those districts where land is dear, and where the Model Bye-laws of the Local Government Board as to areas of space behind houses are in force.

Competitive designs of houses costing about £150 to build have appeared in "Building World." Several of these plans were excellent for the purpose, but now that the cost of material and labour have increased they could not be erected for anything near the sums named; among them, however, may be selected four which are on the lines here laid down, and which could probably be erected for something near £150. That shown by Figs. 121 to 123 is very good in plan and economical in arrangement; the scullery should be omitted, and would result in the saving not only of its cost and the land it stands upon, but also of the land alongside. Omitting the scullery, the house might be erected for £150. The area occupied (including half width of street and passage) is 142 sup. yd., or omitting the scullery, 125 yd.

Size and Height of Rooms.—In an earlier paragraph of this chapter (see p. 140), it has been urged that the living-room

should be large enough to contain with comfort the whole of the family when assembled in the evening. For comfort and for facility of ventilation there should not be less than 300 cub. ft. per head. According to a Memorandum published by the Local Government Board, the height recommended is 9 ft. A room, therefore, of 144 sup. ft. area by 9 ft. high

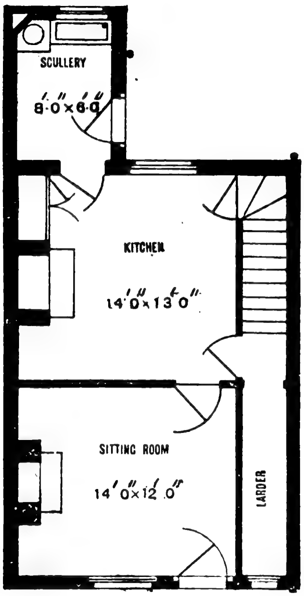


Fig. 121.—Ground Plan of House costing £150.

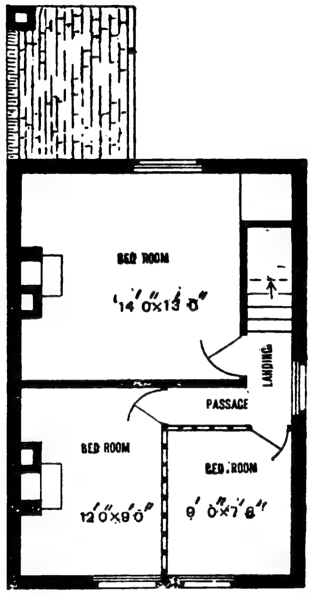


Fig. 122.—First Floor Plan of Fig. 121.

= 1,296 cub. ft., which, divided by 300 cub. ft., implies that four adults and a baby, or two adults and four or five children, would not be overcrowded. (See Chapter VII.)

Bedrooms should be not less than 9 ft. in height, and attics, or rooms partly in the roof, should be 9 ft. in height for two-thirds of their area, not less than 5 ft. at the lowest, and average not less than 8 ft.

Ventilation of Rocms.—Where a room has a fire-place

there is no need to fit up an elaborate and costly ventilating apparatus. All that is necessary is not to stuff up the chimney, and to open the window judiciously. The whole subject of ventilation is dealt with in Chapter VIII. The theory of ventilation is a continuous inflow of fresh air, so arranged as not to produce a perceptible draught, and a constant outflow of foul and exhausted air. The inflow may be man-

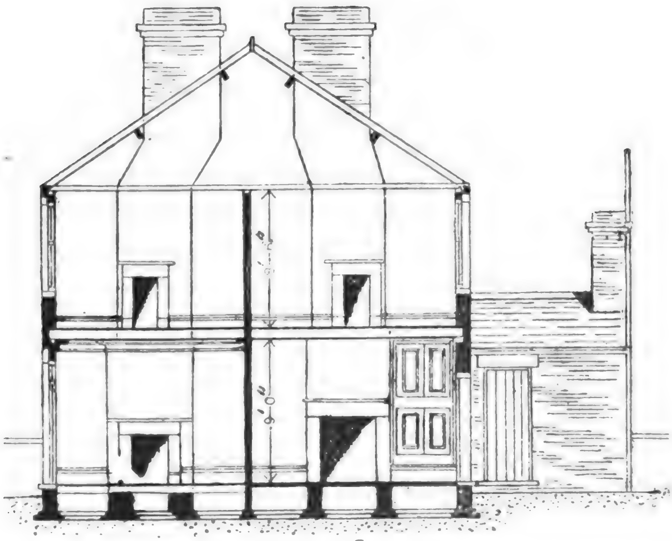


Fig. 123.—Section of Fig. 121.

aged by constructing a Hinckes-Bird bar for the window as described and illustrated in Fig. 105, on p. 130; a bar of timber about 3 in. by 1 in., and in length equal to the width of the window opening. The bar may be either fixed or loose. When loose, the lower sash of the window is opened, the bar laid on edge under the sash, and the sash shut down upon it: there is then an opening between the meeting bars, about ¾ in. in width, by the length of the window, or say 3 ft. = 27 sup. in. of fresh air inlet. When fixed, the lower

bead is taken off, the bar fixed where the bead originally was, and the bead re-fixed on the top of the bar.

The design shown by Figs. 124 to 126 is not so compact

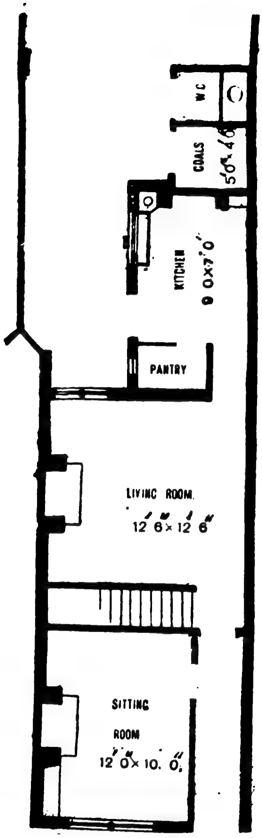


Fig. 124.—Ground Plan of 14-ft. 6-in. House.

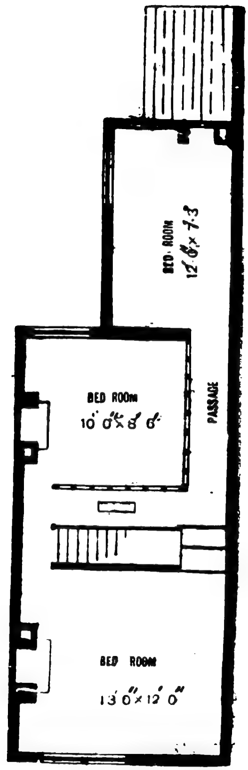


Fig. 125.—First Floor Plan of Fig. 124.

in plan, but has a much narrower frontage. The cost is given at £162 10s. The area of land occupied is about 129 yd.

Space at Rear of Houses.—The majority of local authorities insist upon at least 150 ft. of yard space, though in some districts the requirement is 200 or even 250 sup. ft. The foregoing calculations are based upon an area of 150 sup. ft.

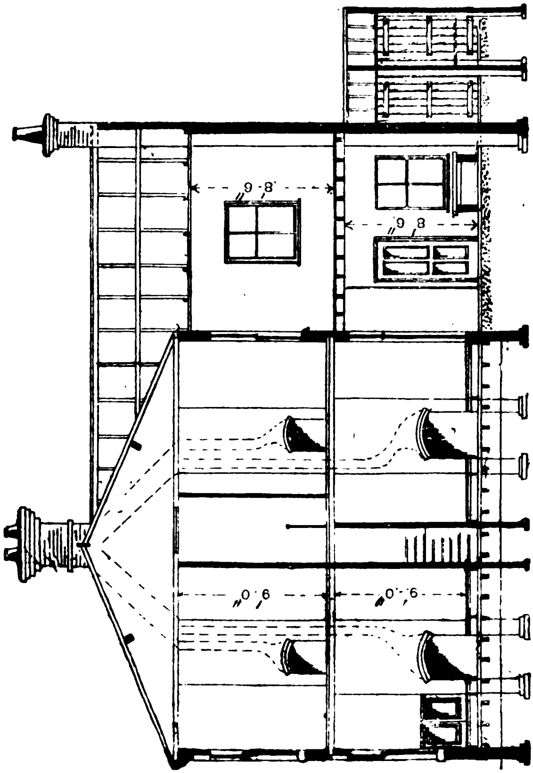


Fig. 126.—Section of Fig. 124.

This has to extend the whole width of the building, and is to be covered with flags, asphalt, concrete, or other impervious paving. The Model Bye-law, however, allows the water-closet and ashpit to be erected on the 150 ft. The distance across the open space varies with the height of the house,

but in no case has it to be less than 10 ft. It will therefore be seen that to obtain this minimum, and the 150 ft. area, the width of the house must be 15 ft. Where the house is less than 15 ft. wide, the distance across must be greater than 10 ft. This, however, is no hardship, as the 10 ft. distance only applies to houses under 15 ft. in height. Where the house is over 15 ft. in height (but under 25 ft.), the dis-

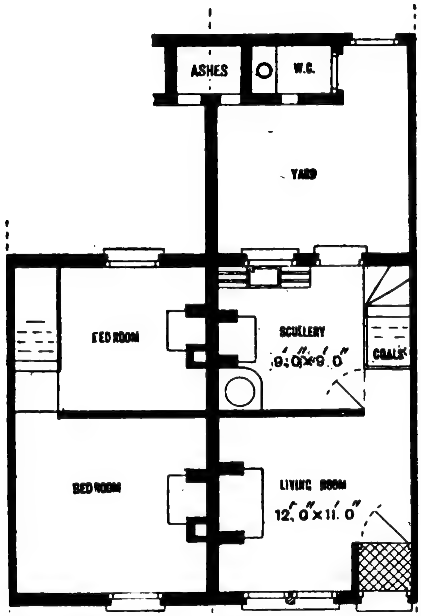


Fig. 127.—Plan of Ground and First Floor of 12-ft. 9-in. House.

tance across the space has to be 15 ft.; the width of the house may therefore be narrowed to 10 ft. without infringement of the regulations. (See p. 108.)

In the design shown by Figs. 127 and 128, in which there is space sufficient for only two bedrooms, the cost is given as less than £100. If the area of the house were slightly increased so as to allow of three bedrooms being arranged

the plan could be carried out for less than £150. The total area occupied (including half street and passage) is 95 yd., but enlarged as suggested would probably reach 110 sup. yd.

Roof Covering.—The roofs will have to be covered with incombustible materials, and for a working man's house the choice is practically limited to slates or tiles, except in those districts where very thin flags are used for the purpose.

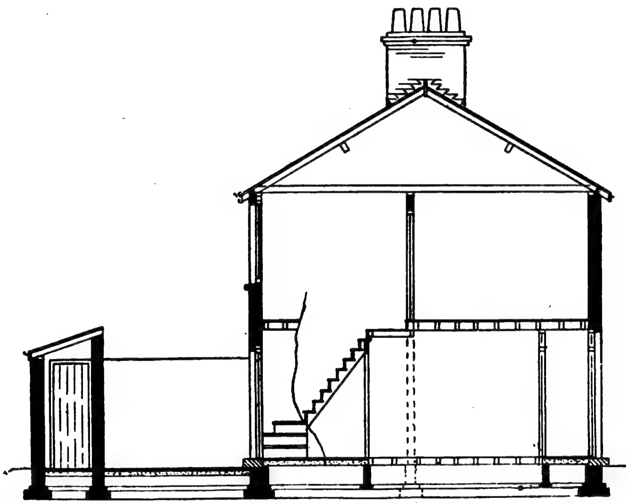


Fig. 128.—Section of Fig. 127.

Thatch, of course, is prohibited. Tiles will be the cheaper in a district where they are made and universally used, and always look better than slates; but generally slates will be found the cheaper and to require less repair in the course of years. As regards roof timbers, though the Local Government Board have not issued a code of sizes, one has been drawn up which has received its sanction. (See p. 84.)

Floors.—The floors of the living-rooms and bedrooms should be of timber; of sculleries, yards, cellars, etc., of

flags or concrete. Here, as for roofs, the Local Government Board approve of the code drawn up and shown on p. 97.

Stairs are also referred to in Chapter VII. The whole subject of staircase construction is dealt with very fully in a companion volume in the series entitled "Practical Staircase Joinery," price 2s., published by Cassell and Co., Ltd.

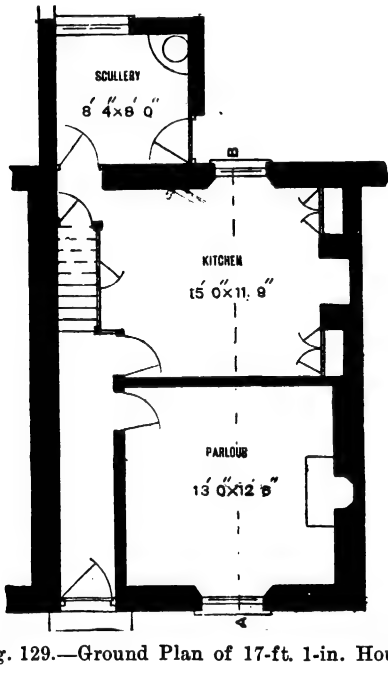


Fig. 129.—Ground Plan of 17-ft. 1-in. House.

The design shown by Figs. 129 to 131 is very much on the lines of Fig. 121 above mentioned. The cost was £150; the area occupied, including the scullery, and the half street and passage, is 134 yd., but if the scullery be omitted it would only be 119½ sup. yd.

Construction of Walls.—These will have to be of good

bricks, stone, or other hard and incombustible materials, properly bonded and solidly put together with lime mortar, cement, or cement mortar. Half-timber work and cavity walls may be used in certain positions and under certain circumstances, in districts where the Model Bye-laws of the Local Government Board have been adopted. The founda-

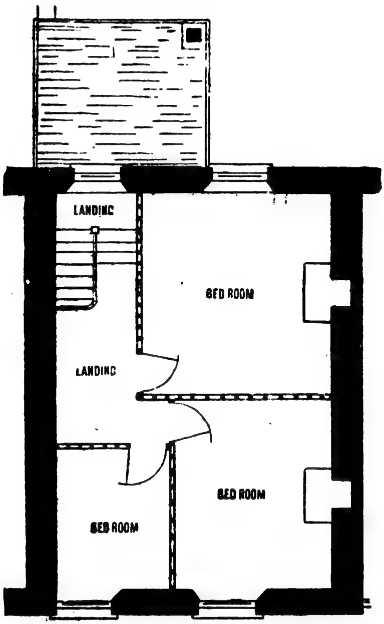


Fig. 130.—First Floor Plan of Fig. 129.

tions will have to be good, and if weak must be strengthened by a thick layer of concrete or by other means; the footings have a certain projection and depth proportionate to the thickness of the wall (see p. 46), and the wall has a certain thickness in proportion to its height (see p. 57). A damp-proof course must be laid upon the walls a few inches above the level of the ground, and if cellars are constructed they

must be surrounded with cavity walls, having two damp-proof courses. All these points are dealt with fully in the earlier pages of this manual.

Frontage.—The frontage or width of a house is a considerable item in reckoning its cost, inasmuch as the cost of paving the front street and the back passage is apportioned according to the frontage lengths of the properties abutting on the streets. This charge may be estimated at nearly 20s. per ft., so that a house 17 ft. 9 in. wide will have to pay £10 more

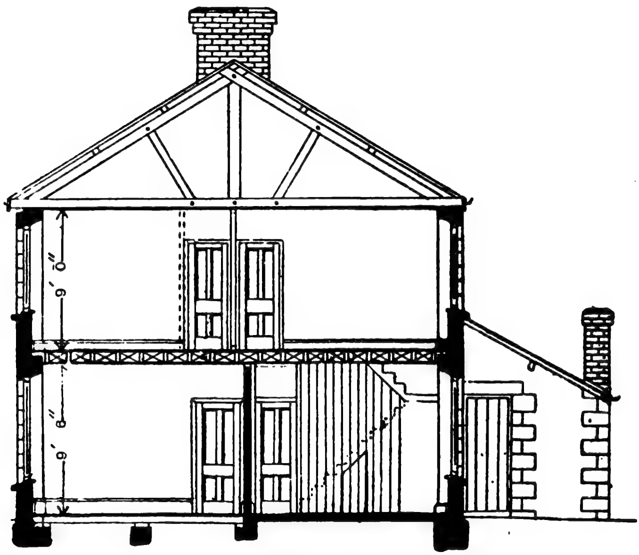


Fig. 131.—Section of Fig. 129.

than a house of only 12 ft. 9 in. frontage; and a house at the end of a row, with a street alongside the gable wall, may have to pay £60 or £70 for paving.

External Appearance.—It is not intended to give designs for elevations for the dwellings. About 200 designs are given in a book entitled "Cheap Dwellings," price 1s., published by Cassell and Co., Ltd.

Arranging these areas and prices in tabular form, we can better compare them :—

Design.	*Frontage.*		*Area.*	*Cost.*		
	ft.	in.	sup. yd.	£	s.	d.
Fig. 117	14	4½	105½	153	0	0
Fig. 119	16	9	123	168	0	0
Fig. 121	17	9	142	148	0	0
Fig. 124	14	6	129	162	10	0
Fig. 127	12	9	95	100	0	0
Fig. 127 (enlarged)	15	0	110	150	0	0
Fig. 129	17	1	119½	150	0	0

Total Cost.—The prospective builder is now in a position to estimate what the smallest house that it is desirable to erect will cost him, and to ascertain whether it is within his means or not. From the table given above it is seen that the average area of land required is about 120 yd., and on reference to the first table we see that 5½d. per yd. chief rent, or at 4 per cent. 11s. 6d. per yd., is the outside price to which it is desirable to go.

The total cost may then be reckoned as follows :—

	£	s.	d.
Land at 4 per cent., not more than ..	65	0	0
House, say	150	0	0
Paving charges, 15-ft. frontage ..	30	0	0
Lawyer, architect, etc.	20	0	0
Total	£265	0	0

Where land is cheap, there may be saved from the above £30.

	£	s.	d.
On the house, possibly	30	0	0
On the paving, possibly	10	0	0
On the lawyer and architect, possibly	5	0	0
Total	£45	0	0

so that the cost of the house complete may be as low as £220. If the street is a highway, there will be nothing to pay for paving the front, and another £10 will be saved.

It will be noticed that all the plans selected are arranged so as to be built in rows. If the builder of one house can get others to join him the cost will be cheaper still.

Drains.—The drains in connection with a working man's house, though not very extensive, should have very close attention. They ought to be well arranged, and constructed in the best style and of the best materials ; they will thus be less likely to become defective, and illnesses as well as the cost of frequent repairs will be avoided They should be constructed of well-burnt glazed socketed earthenware or stoneware pipes, jointed in Portland cement, laid to even falls in straight lines, cut off from the main sewer by an intercepting trap, and ventilated by means of a shaft from the highest point. A 4-in. diameter pipe is amply large for the amount of liquid sewage that it will have to convey, and in no case should it be larger than 6 in. in diameter. The whole question of drains is dealt with in a companion manual on "Sanitary Conveniences."

Sanitary Conveniences.—In many districts a water-closet is compulsory, whilst in many others privies and waste-water closets are allowed. The working man who is building himself a house and is well advised will construct an ordinary water-closet with flushing cistern supplied from the water mains. The whole subject has been dealt with in the manual just mentioned. In rural districts, where the working man has a hobby for gardening, it may be an advantage for him to provide an earth-closet instead of a water-closet ; this, however, can only be done with the approval of the local authority. Earth-closets are dealt with in Chapter VI. of the above-named manual.

Ashpits should be as small as possible in size in order not to encourage the hoarding of ashes and house refuse on the premises. Indeed, the hoarding of house refuse should be minimised as far as possible by burning all the combustible portions either on or under the kitchen fire. A special arrangement for effecting the latter satisfactorily is described in "Sanitary Conveniences." The ashes of the burnt refuse are then carried out with the other ashes, and there is no risk of putrefaction with its accompanying effluvium One ashbin in general use is that known as Dr. Quine's Sanitary Ashbin, manufactured by Sanitaries Ltd., Statham Street,

Pendleton, Manchester. This consists of a pivoted hopper suspended in the yard wall; the refuse is placed in it from the yard, and the scavenger empties it from the outside. Illustrations and further descriptions of these and other ashbins are given in the companion volume on "Sanitary Conveniences."

Conclusion.—The foregoing is a brief attempt to indicate the principal points in Sanitary Construction that a working man erecting a house for himself should bear in mind. Generally this will be the investment of his life's savings and economies, and the investment should be characterised by the care which the importance of the event demands. On the one hand, lavish expenditure is impossible; on the other, undue parsimony is a mistake, the effects of which will be apparent as long as the house stands. A careful and honest builder should be chosen for the work; even though his price is £10 or £15 higher than the lowest, the extra money will be well spent if the work is done well and conscientiously. Careful supervision during construction, and close attention to the sanitary portions of the work, will result in a minimum of repairs, a maximum of comfort, and the absence of death-traps.

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